JAPAN INTERNATIONAL COOPERATION AGENCY

THE REPUBLIC OF SENEGAL
SOCIETE NATIONALE D'ELECTRICITE

No. 2

FEASIBILITY STUDY
ON
DEVELOPMENT OF ELECTRIC POWER SYSTEM
IN
DAKAR AREA

FINAL REPORT

SUMMARY

OCTOBER, 1995

EPDC INTERNATIONAL LTD.
TOKYO, JAPAN

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CARTE AU 1: 50 000

DAKAR

NO-28 XIII (Ouest)

Edité par
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en collaboration avec le
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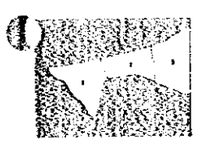
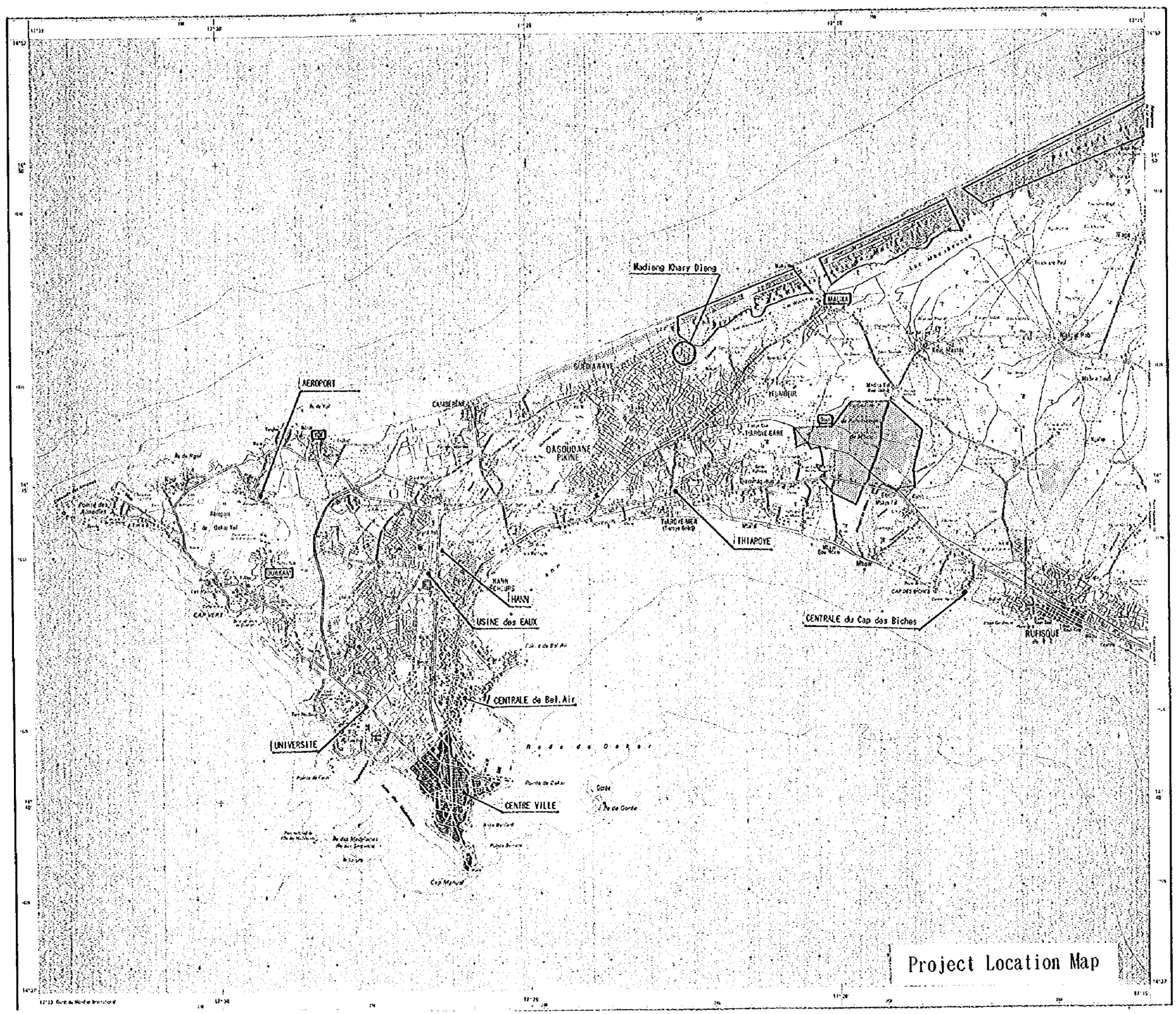
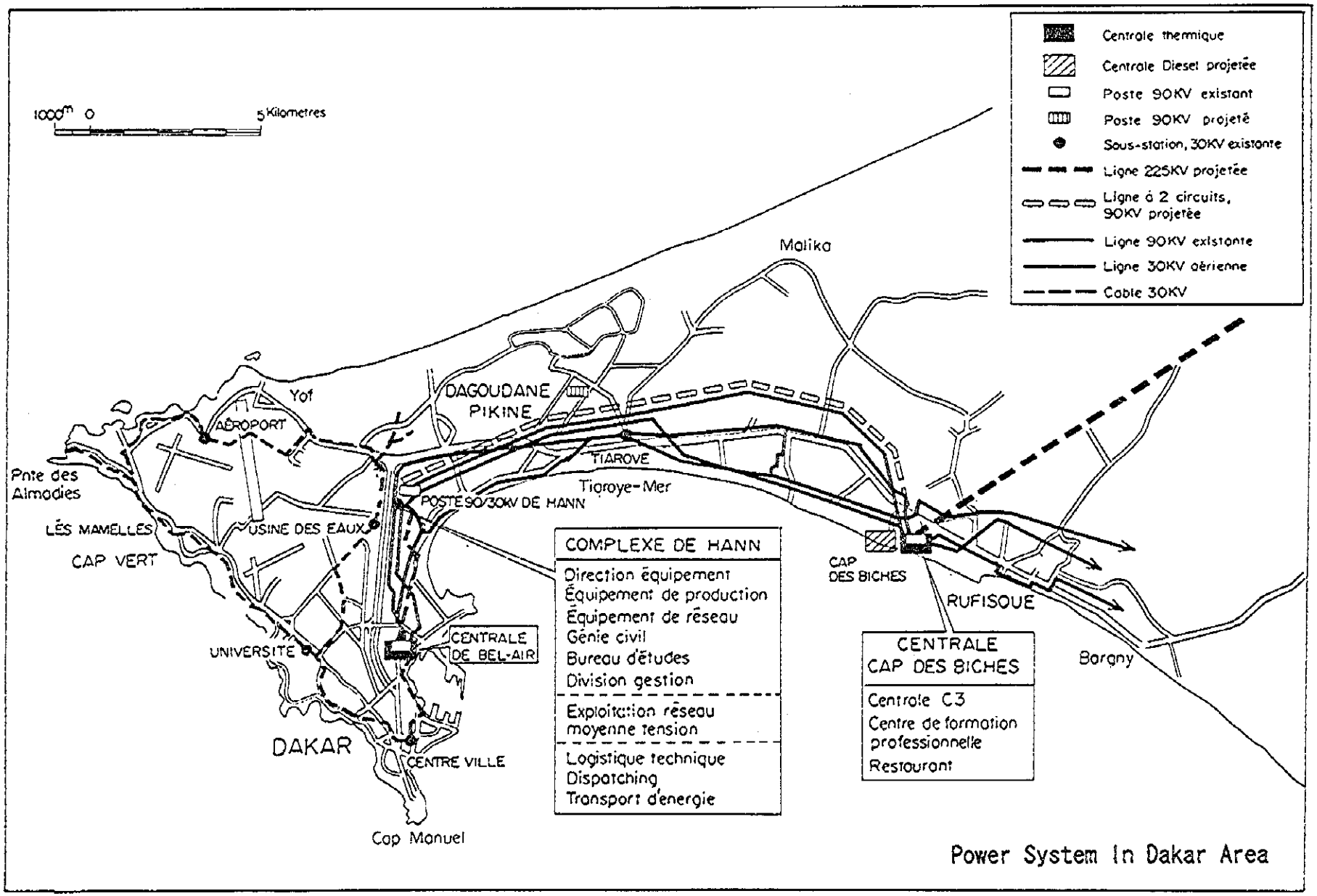
(B.P. 745 Dakar)

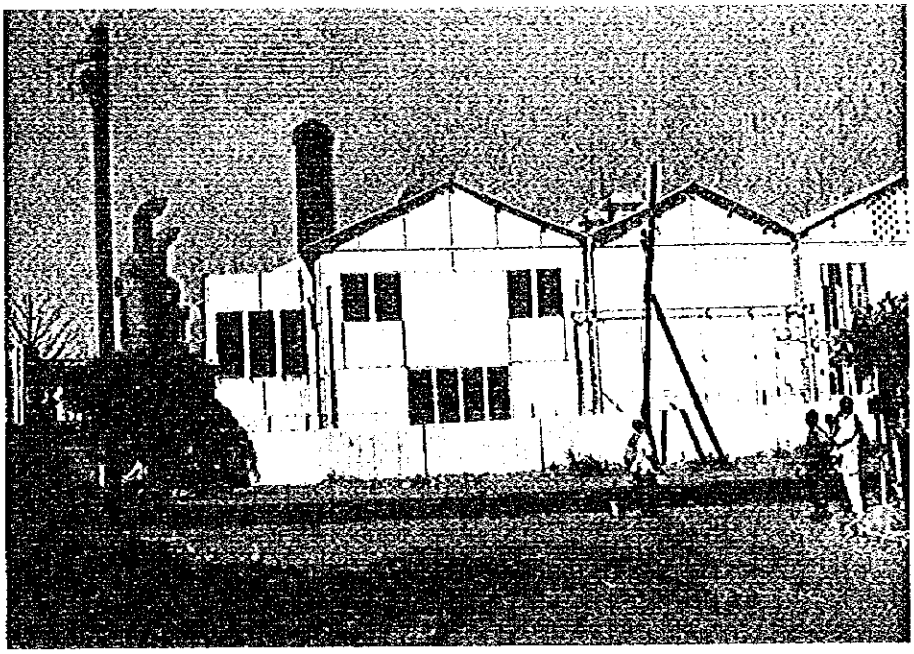
Financement du
FONDS D'AIDE ET DE COOPÉRATION DE LA RÉPUBLIQUE FRANÇAISE

DAKAR
THIÈS
RUFISQUE
GUÉDIAWAYE, MALIKA
Mbao, Rufisque

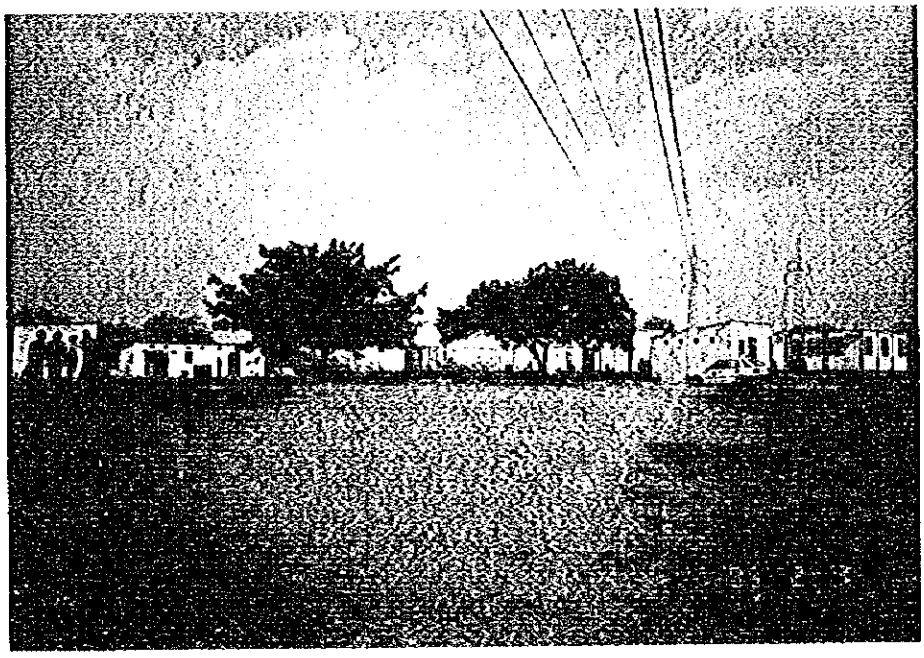





1000m 0 5 Kilometres
Centrale thermique
Centrale Diesel projetée
Poste 90KV existant
Poste 90KV projeté
Sous-station, 30KV existante
Ligne 225KV projetée
Ligne à 2 circuits, 90KV projetée
Ligne 90KV existante
Ligne 30KV aérienne
Cable 30KV
Malika
Yof
AÉROPORT
DAGOUDANE PIKINE
TIAROVE
Tiaroye-Mer
Pnte des Almadies
LES MAMELLES
CAP VERT
USINE DES EAUX
POSTE 90/30KV DE HANN
UNIVERSITE
CENTRALE DE BEL-AIR
DAKAR
CENTRE VILLE
Cap Manuel
CAP DES BICHES
RUFISQUE
Bargny
COMPLEXE DE HANN
Direction équipement
Équipement de production
Équipement de réseau
Génie civil
Bureau d'études
Division gestion
Exploitation réseau moyenne tension
Logistique technique
Dispatching
Transport d'energie
CENTRALE CAP DES BICHES
Centrale C3
Centre de formation professionnelle
Restaurant
Power System In Dakar Area

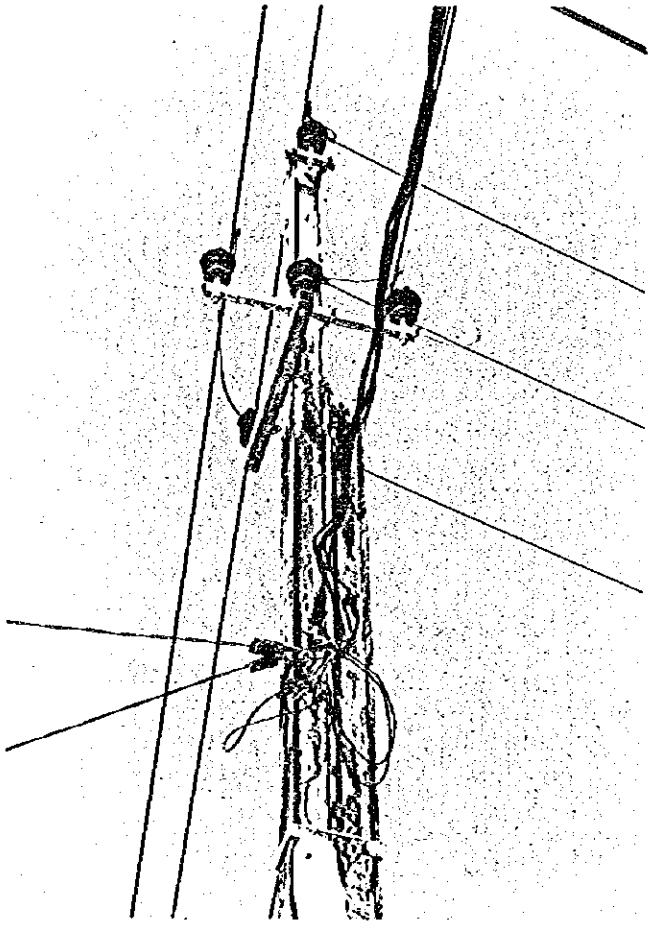


Bel-Air C-I Power Plant



Cap des Biches Plant Yard

Planned Area of Distribution Network
(Madieng Khary Dieng)



6.6 kV Existing Distribution Line
(Camp Penal)

CONTENTS

Final Report (Summary)

CHAPTER 1 CONCLUSION AND RECOMMENDATION

Conclusion:

The study team made three times of field surveys, August 1994, November 1994, January 1995 and discussed with the SENELEC's staffs in charge for the feasibility study on development of electric power system in Dakar area. After reviewing SENELEC's long-term power development master plan and distribution network expansion and rehabilitation master plan which were submitted to the Team in Dakar at the time of the first survey, the team prepared a development of electric power system which should be carried out immediately in a form of interim report and discussed with SENELEC in January 1995, and after obtaining their consent, the team performed a site survey for the feasibility study.

The conclusion acquired as a result of the study on preliminary design, implementation program, construction cost estimation, economic and financial analysis etc. are as follows.

It is concluded that the following development of electric power system in Dakar area is reasonable and feasible from technical and economic view points and should therefore be implemented.

(1) In order to alleviate the power shortage problem and make the existing system possible to apply regular maintenance and checking, two units of 5,000 kW diesel generators in Bel-Air Power Station should be installed and connected to the 30 kV busbar.

(2) In order to solve such problems as overloading in the distribution system, feeder loss, bottle neck and maintaining supply reliability etc., following programs should be executed as an urgent project.

1) Replacement of circuit breakers
2) Improvement of medium voltage distribution lines
3) Expansion of low voltage distribution network
4) Rehabilitation of low voltage distribution network

Recommendation:

The main reason for the power shortage currently affecting Dakar area is deemed to exist in the situation that SENELEC has difficulty to provide fund to expand the system corresponding to remarkable demand increase. Under this circumstance, they have to use the facility even beyond the limit of the equipment without satisfactory maintenance work resulting deterioration of facilities and decreased supply capability as a biggest problem.

The development of electric power system in Dakar area in this report has been provided as a most suitable program in spite of various problems, and it is strongly recommended to do their best to acquire the fund required and execute the project.

When the expansion is finished, power supply system in Dakar area may have some margin and it will become possible to rehabilitate existing generators according to the schedule, utilizing the margin to make machines restore to their normal operating conditions, and maintain stable power generation within the shortest possible time.

For that purpose, deteriorated machines among the existing facility should be completely rehabilitated or retired as scheduled for the machines operating far beyond the life time and try to increase supply reliability.

Facilities in Bel-Air power station are especially old but the location of Bel-Air is considered to be very important even in the future for the purpose of supply reliability and system voltage regulation being located in the centre of the power demand and it should be maintained carefully.

Distribution expansion programs essentially need to be carried out on an on-going basis. Yet, because no long-term investments had been made, conditions regarding the distribution line facilities have significantly deteriorated. It is therefore an urgent priority that serious efforts should be made to obtain the necessary funds and move ahead with the execution of the work to improve the distribution network, reduce power losses. These efforts are needed with the

greatest urgency to ensure the stable supply of electricity to consumers, eliminate the dangers of electrocution and electricity leakage as a result of safer equipment and to bring the benefits of electricity to a greater number of people.

CHAPTER 2 BACKGROUND OF DEVELOPMENT PLAN

2.1 State of the Nation's Power Supply

Power supply in the Senegal is under the comprehensive control and management of SENELEC, the nation's public power corporation taking charge of all power supply activities from the power generation to its distribution to the consumer. The power generated by SENELEC by bunker fuel oil fired boiler, gas turbine and diesel engines is supplied to the consumer through interconnected transmission lines of 225 kV (at present operated at 90 kV) and 90 kV.

The major power stations are Bel-Air power station (installed capacity: 61,200 kW) located in the centre of Dakar City and the Cap des Biches power station (installed capacity: 165,000 kW) located on the outskirts of the city. The nation's total generating capacity, including the independent systems, is given as 251,200 kW.

Details of the facilities are given in Section 2.2.

Both principal power stations, Bel-Air and Cap des Biches, supply their power output into the general grid, termed "reseau interconnecte (RI system)". The power consumption in the RI system accounts for 63% of the nation's total power demand and for 97% of the maximum generated power.

SENELEC also has diesel power plants located in the remote districts of the country. At present, these plants supply their power into their independent systems and it is scheduled that the Saint-Louis and Kaolack systems are to be interconnected to the RI system in 1995 and 1997 respectively.

2.2 Situation of Power Supply in Dakar Area

The Dakar-centered RI system faces difficulties in meeting the increasing power demand in the capital and the lack of funds for construction projects has caused significant delays in the construction of new power generating facilities. At present, supply restriction in

the form of service interruption are a daily occurrence.

Many of the power generating facilities are obsolete and the marginal supply capability is not adequate so that it has not been possible to implement the regular inspection and repair works that are result has been a palpable reduction in power generating capacity and progressive aging of the equipment so that SENELEC has not been able to maintain a stale and dependable power supply.

The distribution facilities are also showing alarming signs of equipment aging as the reinforcement and rehabilitation work has not been carried out as it should have been to meet the power demand increase in the metropolitan area. Because of the mismatched distribution capacities in the various parts of the distribution network, so called bottlenecks and excessive voltage drops are the worst problems occurring. These conditions are a threat to the stable supply of electricity in the region.

Power generation, substation, transmission and distribution line faciliteis in Dakar area are as follows.

(1) Generating Facilities

The breakdown of the generating facilities of RGI system as of July, 1995 are as shown below.

Generator No.	Type	Rated output	Actual output	Operaton start year
Bel-Air Power Station				
G101	Steam turbine	12,800	5,000	1953
G102	Steam turbine	12,800	9,000	1955
G103	Steam turbine	12,800	11,000	1959
G104	Steam turbine	12,800	5,000	1961
G105	Diesel	5,000	5,000	1991
G106	Diesel	5,000	5,000	1991
Sub-total		61,200	40,000	
Cap des Biches Power Station				
G301	Steam turbine	27,500	27,500	1966
G302	Steam turbine	30,000	20,000	1975
G303	Steam turbine	30,000	15,000	1978
TAG1	Gas turbine	16,500	15,000	1972
TAG2	Gas turbine	21,500	19,000	1984
TAG3	Gas turbine	20,000	20,000	1995
G401	Diesel	20,000	20,000	1990
G402	Diesel	20,000	20,000	1990
Sub-total		185,500	156,500	
RGI system total		246,700	196,500	

(2) Transmission Line Facilities

90 kV transmission line facilities in the Dakar area are as follows.

a. Cap des Biches - Hann (3 circuit, 18 km)

b. Hann - Bel-Air (3 circuit 5 km, 1 circuit is not connected)

(3) Substation Facilities

Substation facilities in the Dakar area as follows.

1) Grid substation

a. Bel-Air

(90 kV/6.6 kV)	:	10 MVA x 2
(30 kV/6.6 kV)	:	7.975 MVA x 2
(6.6 kV/6.6 kV)	:	20 MVA x 2

b. Hann

(90 kV/30 kV)	:	80 MVA x 1, 40 MVA x 2

c. Cap des Biches

(90 kV/30 kV)	:	33 MVA x 2

2) Distribution substation (30 kV/6.6 kV)

a.	Usine des Eaux	:	15 MVA x 2
b.	Aeroport Yoff	:	7.975 MVA x 2
c.	Centre Ville	:	15 MVA x 2
d.	Universite	:	15 MVA x 2
e.	Thiaroye	:	7.975 MVA x 2

(4) Distribution Line Facilities

Distribution line facilities in the Dakar area as of December 1994 are as follows.

1) Medium voltage distribution line

a. 30 kV

Underground line	:	142 km
Overhead line	:	149 km

b. 6.6 kV

Underground line	:	130 km
Overhead line	:	125 km

2) Distribution poste

a.	30 kV/low voltage	:	298
b.	6.6 kV/low voltage	:	830

2.3 Necessity of Development Plans

(1) Generating Facilities

The lack of funds has caused a delay in the execution of much-needed power development programs, to the progressive aging and deterioration of the facilities and the failure to implement the necessary regular maintenance inspections and repairs. The consequence of this is that steam turbines output have seriously dropped. This has prevented SENELEC from meeting the increasing demand for electricity and has necessitated the use of supply restrictions on a daily basis so that the stability and reliability of power supply has been compromised. To resolve these problems, it will be essential to increase the power generating facilities so that SENELEC can avail itself of the reserve capacity to shut down the existing plant for maintenance and repair as needed. This will be of vital importance for the restoration of the facilities as a whole.

(2) Distribution Line Facilities

SENELEC has failed to implement the appropriate reinforcement, expansion and rehabilitation work on its existing distribution network in the Dakar area to meet the increasing demand in the urban area. In consequence, bottlenecks or excessive voltage drops occur in many parts of the distribution network, thwarting SENELEC's commitment to the assurance of a dependable power supply to its consumers.

Through the increasing load makes it essentially imperative to expand the distribution network, SENELEC has not been able to carry out the necessary extension work until the present due to the lack of funds and the shortage of materials.

Obsolescence is another problem, seeing that the distribution facilities have now been in service for over 30 years since they were first installed. Equipment aging is progressing and the rate of deterioration is accelerated by salt contamination.

At the same time, the government of the SENEGAL and the Dakar City Authorities has developed housing area in an attempt to resolve the

overpopulation problems in the inner city areas of the capital and cope with the influx of a growing migrant population from the regions into the city. Under these policy, housing estates are being created on the suburban fringe of Dakar. The situation is that these new housing estates are not being properly supplied with electricity.

In view of the above, it will therefore be necessary to expand the distribution network so that the new consumer can enjoy the benefits of electrification. The obsolete facilities create a need for improving the reliability of the power supply and the problems caused by the deteriorated facility are a threat to the safety of the resident so that it will be essential to execute the expansion and rehabilitation work on the distribution line facilities on an urgent basis.

CHAPTER 3 DEVELOPMENT OF ELECTRIC POWER SYSTEM

3.1 Development Plan

Development of electric power system was prepared as a plan of which realization is urgently required by reviewing the SENELEC's "Master Plan Study of Long-term Power Development Plan" and "Master Plan Study of Electrification in Dakar area". Development of electric power system is summarized as follows.

(1) Power Generating Facilities

(Extension of diesel power generating facilities)

Capacity of generating facilities	:	5,000 kW x 2
Bus bar to which new facilities be connected	:	30 kV bus
Step-up transformer	:	6.6/30 kV, 7,500 kVA x 2
Connecting cable	:	30 kV Power cable about 200 (m)
Site of installation	:	In the premises of Bel-Air power station

The relevant drawing of power generating facilities are as follows.

Fig. 3.1-1 Ground Plan of Bel-Air Power Complex
Fig. 3.1-1 Arrangement of C-I Building
Fig. 3.1-1 Single Line Diagram (Bel-Air)

(2) Distribution Line Facilities

a. Replacement of circuit breakers

Name of s/s	7.2 kV CB	36 kV CB
- Centre Ville	5	2
- Universite	5	2
- Aeroport Yoff	3	2
- Thiaroye	2	-
Total	15 (sets)	6 (sets)

b. Improvement of medium voltage distribution lines
(Replacement of the existing 6.6 kV overhead distribution lines with 30 kV underground cables)

-	Dispensaire	:	2.15 (km)
-	Dag. Pikine	:	0.8 (km)
-	Fann	:	0.35 (km)
-	Rte de Rufisque	:	12.1 (km)
-	Dag. Pikine	:	1.7 (km)
-	Batterie Yoff	:	2.0 (km)
-	Labo Pecherie	:	2.9 (km)
-	Yeumbeul	:	1.05 (km)
	Total		23.05 (km)

c. Expansion of low voltage distribution network

-	Madieng Khary Dieng	:	40 (ha)
-	Route de Boune	:	50 (ha)
-	Route de Marine	:	40 (ha)
-	Route de Malika	:	40 (ha)
-	Malika	:	50 (ha)
	Total		220 (ha)

d. Rehabilitation of low voltage distribution network

	Name of poste		Main line (km)	Branch line (km)
-	Rue 10	:	0.45	0.60
-	El Mansour	:	0.85	1.00
-	Rue 10 x 11	:	0.45	0.70
-	Rue 10 x Bene	:	0.50	0.70
-	Canal IV	:	0.45	0.70
-	Amite II	:	0.60	0.80
-	Yoff Layenes	:	1.40	3.00
-	Yoff Centre	:	0.70	2.00
-	Yoff Village	:	1.00	2.40
-	N'Gor	:	1.10	2.30
-	Ouakam Boulga	:	1.00	1.70
-	Ouakam Taglou	:	0.70	0.60
-	Ouakam Ecole	:	0.80	0.60
	Total		10.0 (km)	17.1 (km)

3.2 Construction Cost and Schedule

3.2.1 Construction Costs

The total construction costs for the development of electric power system are as stated below.

Power generating facilities	Foreign currency portion (Million Yen)	Local currency portion (Million Yen)	Total (Million Yen)
1) Generating facilities	1,675.0	91.9	1,766.9
(Incl. contingency)	1,926.3	105.7	2,032.0
2) Power distribution facilities	681.3	104.7	786.0
(Incl. contingency)	783.4	120.4	903.8
(Breakdown of distribution facilities)			
a. Replacement of circuit breakers	28.6	2.4	31.0
b. Improvement of medium voltage distribution lines	300.4	47.8	348.2
c. Expansion of the low voltage distribution network	278.9	41.5	320.4
d. Rehabilitation of the low voltage distribution network	73.4	13.0	86.4

Notes

(1) Breakdown of construction costs borne by the Senegal

1) Power generating facilities
   - Removal and construction of de-mineralized water tank (30 t) x 3 inside the C-I building
   - Removal of de-mineralized water tank (40 t) x 2 outside the building
   - Removal of pipes and heat exchangers inside the C-I building
   - New construction of de-mineralized water tank

2) Distribution line facilities
   a. Replacement of circuit breakers
      - Removal of existing equipment
      - Modification of installation site
      - Equipment installation

b. Improvement of medium voltage distribution line
   - Removal of existing overhead distribution lines
   - New erection and modification of distribution postes
   - Equipment installation in distribution postes
   - Laying of the underground cables

c. Expansion of the low voltage distribution network
   - Modification of existing distribution postes
   - Construction of new distribution postes
   - Laying of the underground cables
   - Pole erection and stringing work
   - Connection to consumers

d. Rehabilitation of the low voltage distribution network
   - Removal of existing facilities
   - Pole erection and stringing work
   - Connection to consumers

(2) The price of materials and equipment as of February, 1995 was adopted for cost estimation.

The exchange rate is as follows.
- 1 US$ = ¥99.85
- 1 US$ = FCFA 528
- 1 FF = ¥19.10

(3) Construction Costs

1) Power generating facilities

The construction of power generating facilities will be executed by full-turn-key basis and include the following costs.

a. Materials and equipment cost
b. Transportation cost
c. Installation cost
d. Administration cost
e. Consultant fee

2) Distribution line facilities

The construction work and installation of equipment will be executed by SENELEC because the supply of materials and equipment is considered as the scope of work, and include the following costs.

a. Materials and equipment cost
b. Transportation cost
c. Administration cost
d. Consultant fee

3.2.2 Construction Schedule

1) Power Generating facilities

Fig. 3.2-1 shows the construction schedule of power generating facilities.

2) Distribution line facilities

Fig. 3.2-2 shows the construction schedule of distribution line facilities.

These construction schedule shows the schedule after signing with the contractor.

CHAPTER 4 FINANCIAL AND ECONOMIC EVALUATION

We have assessed the viability of the Project from both the financial and economic points of view, primarily by calculating the FIRR and EIRR of the Project and then comparing the two with an assumed discount rate of 12%. The FIRR of the Project was computed at 14.2%, and the EIRR of the Project at 15.5%. These results indicate that the Project is fundamentally sound. (In analyzing the FIRR of the Project, no considerations were made regarding financing costs, which could distort the underlying viability of the Project.)

Sensitivity tests were performed for these rates. It was found that the Project involved only a small risk in economic terms, as the EIRR fell below the cut-off rate of 12% only under the worst scenario, among three scenarios assumed, where the investment capital requirement for the Project exceeded its estimate by 10% and the Project's benefit was 10% lower than expected. Compared with the EIRR, the FIRR of the Project is more sensitive. It was found that the FIRR fell below the 12% level even under a scenario where the investment cost was not changed from the original estimate but the revenue was lowered by 10% from the original estimate.

The FIRR of the equity invested in the Project was computed at 14.6% under an assumed financing scenario where the equity-loan ratio was 30% to 70%, and the loan was repayable in 10 years at an interest rate of 12%, at the rate of which commercial loans are available for SENELEC. The FIRR is sufficiently high. However, the debt coverage rate, which is projected to vary from 1.03 for the first year of the loan repayment to 1.08 for the tenth year, will not be acceptable for lenders of the loan, who usually expect the ratio to be 1.5 or higher. It was found that the rate would be improved little, even if the loan amortization period was extended to 20 years. If the equity ratio is raised to 50%, the coverage ratio will rise to 1.45 for the first year of loan replacement. In view of the current financial position of SENELEC, a financing scenario with an equity ratio of 50% is unlikely to be practicable or feasible. With an assumed interest rate of 3 percent, the IRR on the equity invested becomes sufficiently high at 25%, and the debt coverage ratio acceptably high at 1.69 for first year of loan repayment. In sum, although the FIRR of the Project, which does not take the impact of financing costs into consideration, is satisfactorily high, it appears that the Project

becomes financially feasible only if a loan is available at a considerably low interest.

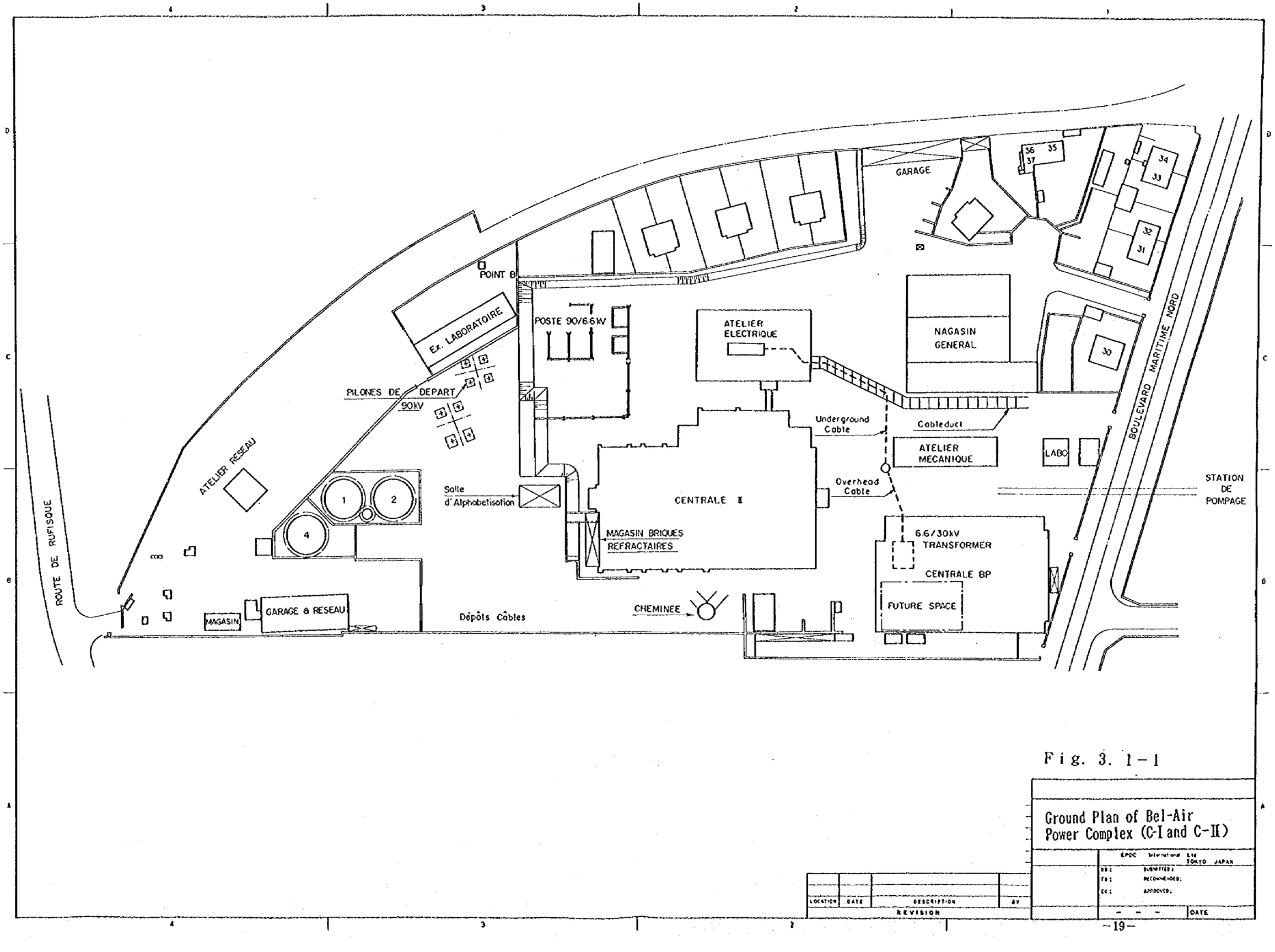


Fig. 3. 1-1

Ground Plan of Bel-Air Power Complex (C-I and C-II)

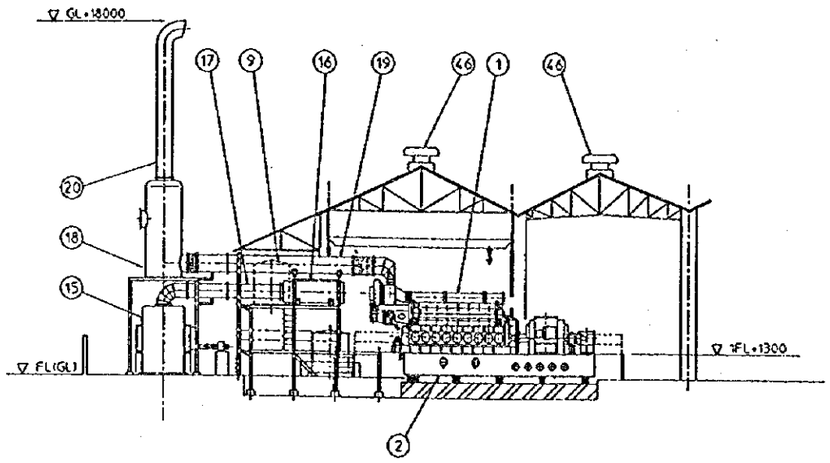
EPDC International Ltd TOKYO JAPAN

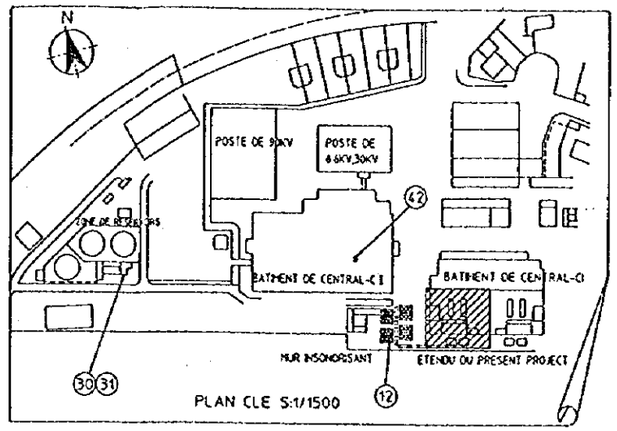
DR: SUBMITTED:
CH: RECOMMENDED:
QC: APPROVED:

DATE

LOCATION	DATE	DESCRIPTION	BY
REVISION			

PLAN RECORD	REF DRAWING NO		REF ORDER NO	





No.	DESIGNATION	QTE	REMARQUES
47	TABLEAU DE DISTRIBUTUON D' ECLAIRAGE	1+1	
46	VENTILATEUR DE TOIT	8+8	FOURNITURE
44	CONDUITES DE VENTILATION	1+1	
43	COMPRENDRA DES SOUFFLANTES DE VENTILATION	4+4	
42	TABLEAU DE SURVEILLANCE A DISTANCE	1	
41	TABLEAU D' ALIMENTATION C.C.	1+1	
40	TRANSFORMATEUR AUXILIAIRE	1+1	
39	TABLEAU DE COMMANDE DES MACHINES AUXILIAIRES	1+1	
38			
37	TABLEAU DE CIRCUIT DE L'EXCITATEUR	2+2	
36	TABLEAU DE DISJONCTEUR D' ALTERNATEUR	2+2	
35	TABLEAU DE COMMANDE D' ALTERNATEUR	2+2	
34	TABLEAU D' INSTRUMENTS DE MOTEUR DIESEL	2+2	
33	SUPPORT DE RESERVOIR	1+1	
32	POMPE DE TRANSFERT D' HUILE	1+1	
31	POMPE DE TRANSFERT DE CARBURANT DIESEL	2	
30	POMPE DE TRANSFERT DE MAZOUT	2	
29			
28			
27			
26	POMPE DE TRANSFERT D' HUILE USEE	1	
25	SEPARATEUR D' EAU HUILEUSE	1	
24	POMPE DE TRANSFERT D' EAU HUILEUSE	1	
23	RESERVOIR DE SEPARATION DE BOUE	1	
22	UNITE D' RESERCOIR DE BOUE	2+2	
21	UNITE D' RESERCOIR DE VIDANGE DE GAS OIL	2+2	
20	CHEMINEE	2+2	
19	GAINE D' ECHAPPEMENT	2+2	
18	SILENCIEUX D' ECHAPPEMENT	2+2	
17	GAINE D' ASPIRATION	2+2	
16	SILENCIEUX D' ASPIRATION	2+2	
15	FILTER D' ADMISSION D' AIR	2+2	Type a inertie et a bain d' huile
14	POMPE D' ALIMENTATION D' EAU	2	
13	POMPE D' EAU DE REFROIDISSEMENT SECONDAIRE	2+2	
12	RADIATEUR D' EAU DE REFROIDISSEMENT	2+2	
11	RESERVOIR D' EXPONSION D' EAU DE REFROIDISSEMENT DE CHEMISE	1+1	500 ℓ
10	RESERVOIR DE SERVICE DE CARBURANT DIESEL	1+1	2500 ℓ
9	RESERVOIR DE SERVICE DE MAZOUT	1+1	5000 ℓ
8	RESSERVOIR TAMPON DE MAZOUT	1+1	5000 ℓ
7	UNITE D' SURALIMENTATION GRAISSAGE	2+2	
6	SKID D' EQUIPMENT AUXLIAIRE (4)	2+2	Tuyauterie
5	SKID D' EQUIPMENT AUXLIAIRE (3)	1+1	Epurateur de mazout
4	SKID D' EQUIPMENT AUXLIAIRE (2)	2+2	Unite d' alimentation de gas oil, epurateur d' huile de graissage
3	SKID D' EQUIPMENT AUXLIAIRE (1)	2+2	Unite d' huile de graissage,unite d'eau de refroidissement,unite d' coagrine
2	SOCLE COMMUN	2+2	Et reservir collecteur
1	MOTEUR DIESEL ET ALTERNATEUR	2+2	

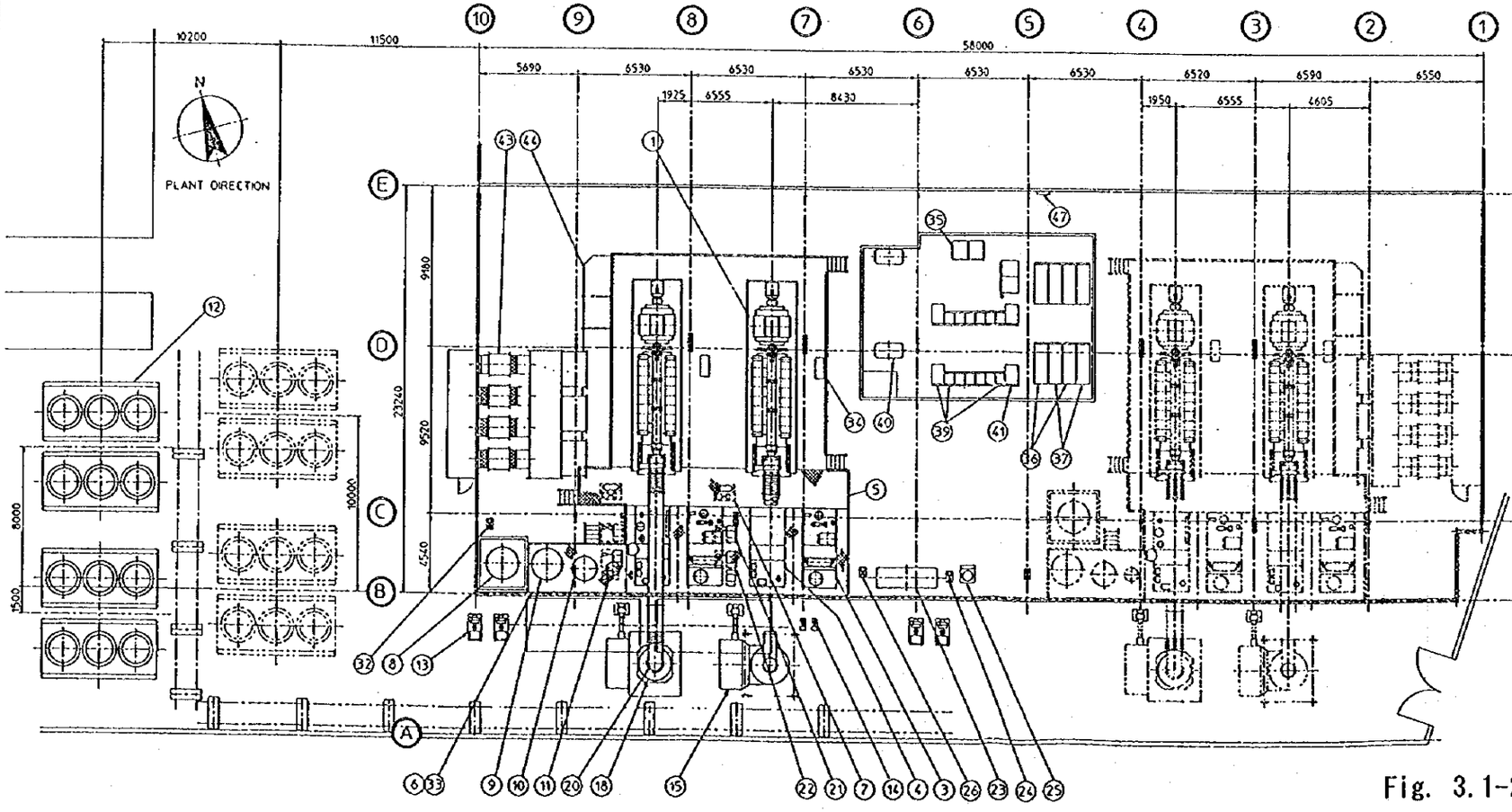


Fig. 3.1-2 Arrangement of C-I Building

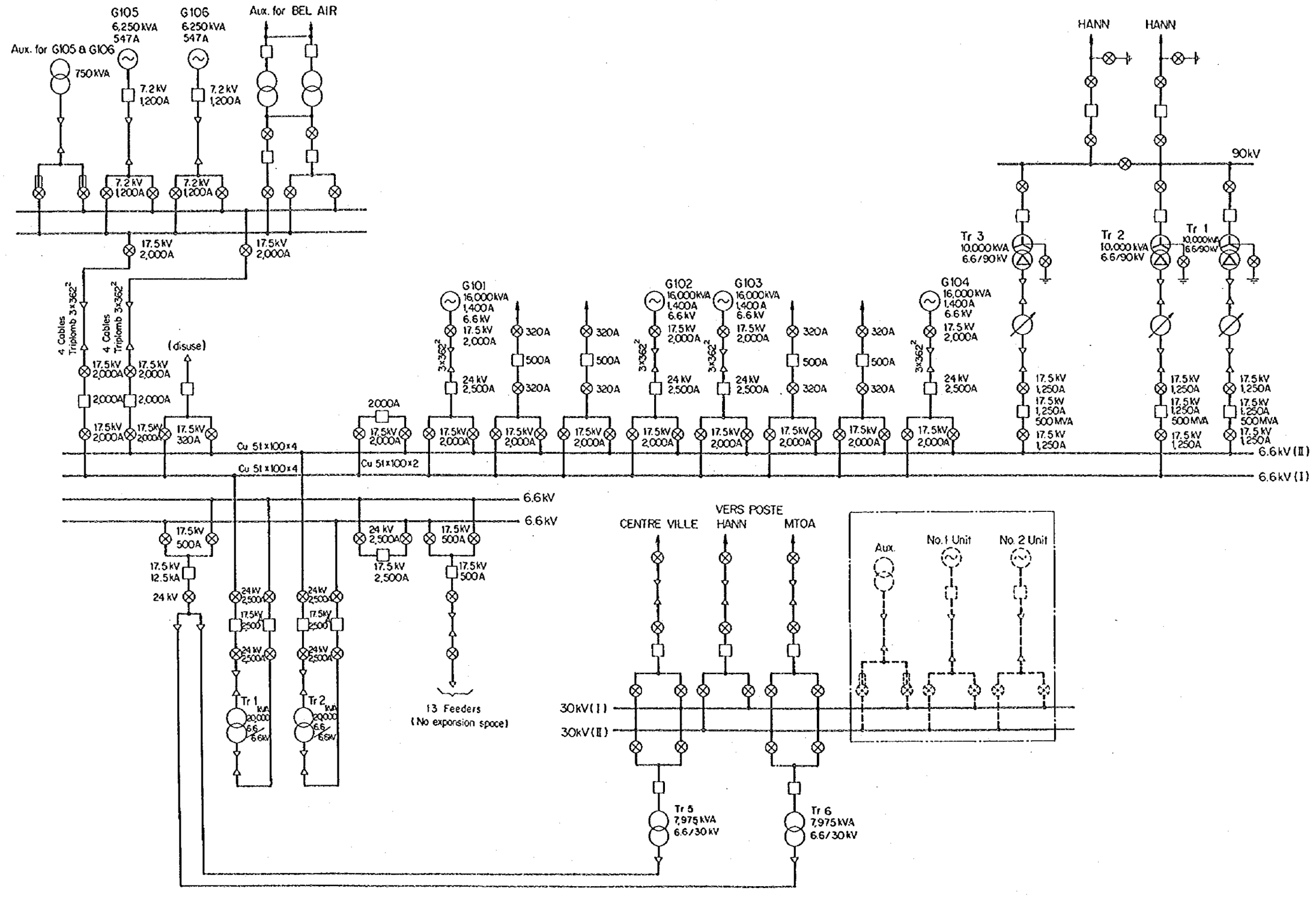
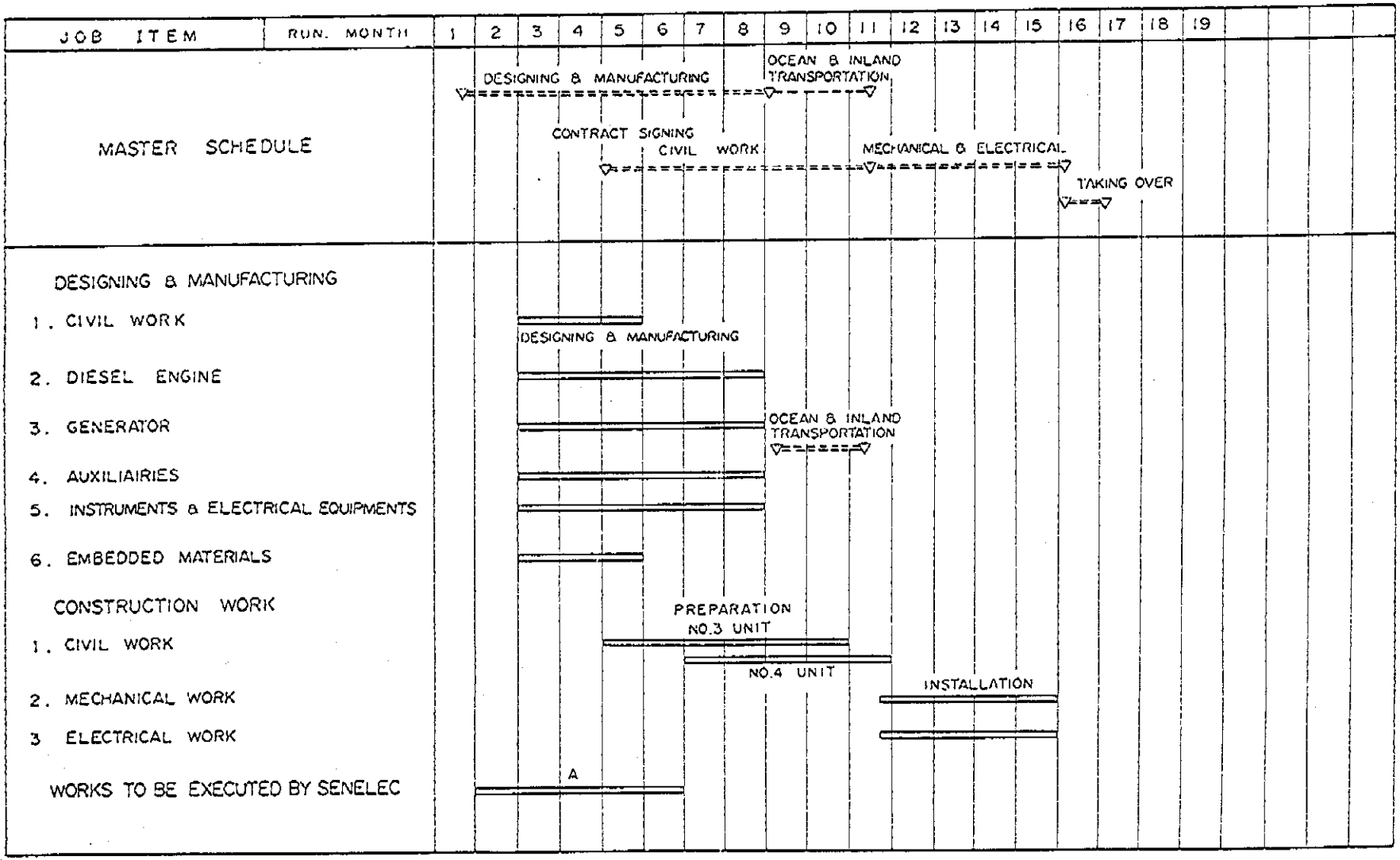


Fig. 3.1-3 Single Line Diagram (Bel-Air)

Fig. 3.2-1 Standard Schedule for 5,000kW Diesel Engine



※ A REMOVAL of BOILER WATER TANK
REMOVAL of COOLING WATER TANK
REMOVAL of OIL INCINERATOR

Fig. 3.2-2 Schedule for Distribution Lines