2.2.2 Change in Population and Electric Energy Forecasting

Table 2.2.2 represents the change in population in each department from 1981 to 1985 and Table 2.2.3 shows power demand. Table 2.2.4 indicates the estimation of per capita power demand based on the above factors and their average annual increase rate. Departments whose increase rate exceeds 10% are Meta, Choco and Antioquia.

Table 2.2.2 Change in Population in 1981 and 1985 and Estimated Population in 1989

(Unit: Person)

No.	Department	Population in 1981	Average Growth Rate (%)	Population in 1985	Estimated Population in 1989
1	Antioquia 2)	1,564,094	2.3	1,713,151	1,876,000
2	Boyaca	1,062,056	0.8	1,097,618	1,135,000
3	Caldas	1,106,584	1.5	1,175,546	1,249,000
4	Cauca	724,514	2.4	795,838	874,000
5	Cundinamarca 3)	1,281,824	1.9	1,382,360	1,491,000
6	Choco	228,155	1.6	242,768	258,000
7	Huila	580,342	2.8	647,756	723,000
8	Meta	360,020 1)	4.6	412,312	494,000
9	Nariño	941,519	2.0	1,019,098	1,103,000
10	Santander	1,325,491	2.1	1,438,226	1,560,000
11	Tolima	999,427	1.3	1,051,852	1,107,000
12	Risaralda 4)	258,770	2.7	287,999	321,000
13	Quindio 5)	357,865	1.4	377,860	399,000
14	Putumayo	98,730	4.9	119,815	145,000
	Total	10,889,391	1.9	11,762,199	12,735,000

1) This data in 1982
2) Teritory of EPM is not included.
3) Teritory of EEEB is not included.
4) Data of EPP
5) Data of CRQ and E. P. de Armenia

(Source: Informe Estadistico Resumen 1981-1985)

N.B., 1) Population of major cities in 1985 is as follows:

a) Bogota (Bogota D.E.) : 3,974,813
b) Medellin (Antioquia) : 1,418,554
c) Cali (Valle) : 1,323,944
d) Barranquilla (Atlantico) : 896,649

Table 2.2.3 Power Demand

(Unit: GWh)

No.	Department	Power Demand in 1981	Average Increase Rate (%)	Power Demand in 1985	Estimated Power Demand in 1989
1	Antioquia 2)	596	13.1	974	1,593
2	Boyaca	465	7.8	628	848
3	Caldas	668	8.0	908	1,235
4	Cauca	190	10.2	280	413
5	Cundinamarca 3)	356	2.9	399	447
6	Choco	23	20.0	48	99
7	Huila	209	11.7	326	507
8	Meta	79 1)	34.0	190	613
9	Nariño	274	9.3	391	558
10	Santander	507	9.1	718	1,017
11	Tolima	398	7.1	524	689
12	Risaralda 4)	269	6.7	349	452
13	Quindio 5)	144	8.2	196	269
14	Putumayo	No Data Available			
	Total	4,178		5,931	8,740

1) This data in 1982
2) Teritory of EPM is not included.
3) Teritory of EEEB is not included.
4) Data of EPP
5) Data of CRQ and E. P. de Armenia

(Source: Informe Estadistico Resumen 1981-1985)

Table 2.2.4 Power Demand per Capita

(Unit: kWh/person)

No.	Department	1981	Average Growth Rate (%)	1985	Estimated Energy in 1989
1	Antioquia 2)	380	10.7	570	850
2	Boyaca	530	1.9	572	613
3	Caldas	604	6.3	772	989
4	Cauca	260	7.8	352	473
5	Cundinamarca 3)	278	1.1	290	300
6	Choco	100	18.9	200	380
7	Huila	360	8.6	500	701
8	Meta	219 1)	28.2	461	1,241
9	Nariño	291	7.2	384	506
10	Santander	382	6.9	499	652
11	Tolima	398	5.8	498	622
12	Risaralda 4)	1,040	3.9	1,212	1,408
13	Quindio 5)	400	6.8	519	674
14	Putumayo		No Data Available		
	Total	403	6.8	525	683

1) This data in 1982
2) Teritory of EPM is not included.
3) TEritory of EEEB is not included.
4) Data of EPP
5) Data of CRQ and E. P. de Armenia

(Source: Informe Estadistico Resumen 1981-1985)

2.2.3 Present Condition and Forecast of Demand Supply Balance

The installed capacity and peak demand in each department in 1985 are shown in Table 2.2.5. The demand supply balance in power demand and peak demand is kept in Boyaca Department, and that in the peak demand is kept in Santander Department. In those except the above two departments, the demand supply balance is not kept. Among the departments, Choco and Putumayo depend all electric energy on the supply from the other power companies and Antioquiquia, Meta and Quindio depend 90% or more electric energy on such supply.

On the other hand, the planned constructions of generating facilities in each department are for hydraulic power plants, as shown in the following table.

Construction Plan of Power Plants

No.	Department	Plant Name	Property	Capacity (MW)	Estimated Commencement of Operation
1	Antioquia	Rio Grande	EPM	322.5	1990
2	Cundinamarca	Guavio	EEEB-ISA	1,000.5	1990
3	Choco	Bahia Sorano	ICEL	2.4	1991
4	Caldas	Miel-I	CHEC	405	1993

As the prospect of power demand, the self-sufficient rate of electric energy is expected to be approx. 54%, as a result of Betania hydroelectric power plant's operation in 1987. The self-sufficient rate will be reduced and dependency on the supply from the other power companies will be increased until the start of MIEL-I in 1993.

Table 2.2.6 shows the transition of demand composition in each department in recent six years from 1981 to 1986. In Choco and Meta Departments, all the power consumption for residential , commercial and industrial uses show 10% or more increase rates.

Table 2.2.5 Balance of Supply and Demand in 1985

No.	Department	Installed Capacity (MW)	Peak Demand (MW)	Demand Factor (%)	Energy (GWh)	
					Generating	Demand
1	Antioquia 2)	12.5	130.3	1,042	45	974
2	Boyaca	174.6	128	73	989	628
3	Caldas	199	294.4	148	601	908
4	Cauca	33.4	68.8	206	120	280
5	Cundinamarca 3)	10	84.9	849	51	399
6	Choco	0	10.5	-	0	48
7	Huila	14	55.8	399	40	326
8	Meta	1.6 1)	36	2,250	3	190
9	Narino	39.4	74.1	188	176	391
10	Santander	188.6	143.8	76	590	718
11	Tolima	66	103	156	239	524
12	Risaralda 3)	18.6	59.6	320	72	349
13	Quindio (4)	5.4	41.9	776	3	196
14	Putumayo	0	2.2	-	0	18
	Total	763.1	1,233.3	-	3,669	5,949

1) This data in 1982
2) Teritory of EPM is not included.
3) Teritory of EEEB is not included.
4) Data of EPP
5) Data of CRQ and E. P. de Armenia

(Source: Informe Estadistico Resumen 1981-1985)

Table 2.2.6 Energy Consumption by Category (1981 - 1986)

(Unit: GWh)

Department	Category	1981	1982	1983	1984	1985	1986	Average Increase Rate (%)
Antioquia except Medellin	Residential	353	408	471	528	571	635	12.4
	Commercial	52	57	59	57	60	67	5.2
	Industrial	27	29	35	45	48	52	14
	Other	47	53	52	53	68	39	-3.7
	Total	479	547	617	683	747	793	10.6
Boyaca	Residential	123	115	107	122	134	140	2.6
	Commercial	22	18	15	17	18	19	0
	Industrial	205	243	236	246	246	268	5.5
	Other	25	39	46	56	56	61	19.5
	Total	375	415	404	441	454	488	5.4
Caldas	Residential	285	282	294	345	379	410	7.5
	Commercial	51	47	47	55	60	65	5
	Industrial	151	133	140	162	164	163	1.5
	Other	24	23	28	30	31	67	22.8
	Total	511	485	509	592	634	705	6.6
Cauca	Residential	99	125	125	144	142	144	7.8
	Commercial	11	13	11	12	12	12	1.8
	Industrial	9	7	9	15	13	17	13.6
	Other	17	17	21	22	18	17	0
	Total	136	162	166	193	185	190	6.9
Cundinamarca except Bogota	Residential	130	103	94	106	121	127	-0.5
	Commercial	45	31	24	28	32	32	-6.6
	Industrial	81	75	73	78	85	90	2.1
	Other	45	102	122	125	113	109	19.4
	Total	301	311	313	337	351	358	3.5
Choco	Residential	10	11	16	20	25	32	26.2
	Commercial	2	3	3	4	4	5	19.9
	Industrial	1	1	1	1	2	2	14.3
	Other	2	2	3	3	5	6	24.4
	Total	15	17	23	28	36	45	24.6
Huila	Residential	81	90	99	110	135	132	10.3
	Commercial	23	22	23	26	28	27	3.3
	Industrial	20	28	45	48	51	37	13.1
	Other	36	37	42	42	50	46	5
	Total	160	177	209	226	264	242	8.6
Meta	Residential	-	30	54	60	66	75	25.8
	Commercial	-	11	20	21	26	31	29.8
	Industrial	-	14	22	25	26	26	16.7
	Other	-	7	14	17	17	16	23.1
	Total	-	62	110	123	135	148	24.3
Nariño	Residential	159	165	179	196	192	191	3.7
	Commercial	16	15	15	15	16	17	1.1
	Industrial	18	18	19	18	23	20	2.1
	Other	19	18	18	19	19	22	2
	Total	212	216	231	248	250	250	3.3
Santander	Residential	205	223	245	266	281	291	7.3
	Commercial	65	66	74	84	87	86	5.7
	Industrial	97	102	105	129	144	127	5.5
	Other	51	53	55	70	78	56	1.9
	Total	419	444	479	549	590	560	6
Tolima	Residential	135	143	157	164	174	178	5.7
	Commercial	42	41	44	45	45	45	1.4
	Industrial	99	113	111	119	128	136	6.6
	Other	40	40	41	45	47	49	4.2
	Total	316	337	353	373	394	408	5.2
Risaralda	Residential	121	126	140	161	169		8.7
	Commercial	26	28	30	36	43	No Data	13.4
	Industrial	36	38	38	49	53	Availa-	10.2
	Other	2	2	3	3	5	ble	25.8
	Total	174	194	211	249	270		9.9
Quindio	Residential	85	68	91	101	104		5.2
	Commercial	12	11	15	16	20	No Data	13.6
	Industrial	8	6	7	7	9	Availa-	3
	Other	9	7	13	13	17	ble	17.4
	Total	114	92	126	137	150		7.1
Putumayo	Residential							
	Commercial							
	Industrial			No Data Available				
	Other							
	Total							

Source: 1. Informe Estadistico Resumen 1981-1985 2. Sistema Electrico del Grupo ICEL 1946-1986

2.2.4 Present Condition and Future Plan of Transmission and Substation Facilities

Table 2.2.7 indicates the condition of transmission and substation facilities in each department in 1985. 230 kV transmission system is operated by Boyaca, Cauca and Santander departments.
Table 2.2.8 shows planned 110 kV or more transmission lines which will be constructed by 1991. After the completion of those plants, the power loss will be reduced.

Table 2.2.7 (a) Total Length of Transmission Lines in 1985

(Unit: km)

No.	Department	Total Length of Transmission Line					
		230 kV	115 kV	66 kV	44 kV	34.5 kV	13.2 kV
1	Antioquia	-	381	-	902.3	-	1,175
2	Boyaca	154	274.4	19.5	20	598.6	964.3
3	Caldas	-	418.3	-	-	525.5	3,464
4	Cauca	268	155.5	-	-	322	1,550
5	Cundinamarca	-	102	-	-	232	1,052.5
6	Choco	-	77	-	-	-	220.6
7	Huila	-	213	-	-	353.4	1,018.8
8	Meta	-	-	-	-	118.2	452.5
9	Narino	-	229	-	-	216	709
10	Santander	100	238.6	-	-	292.3	1,011.6
11	Tolima	-	173	-	-	593	1,200
12	Risaralda	-	7.8	-	-	42	7
13	Quindio	-	-	-	-	65	1,193.7
14	Putumayo	-	-	-	-	No Data Available	

(Source: Sistema Electric del Grupo ICEL 1946-1986)

Table 2.2.7 (b) Total Capacity of Transformer in 1985

(Unit: MVA)

No.	Department	Total Capacity of Transformer (MVA)					
		230/115	115/66	115/44-34.5	115/13.2	66-44/13.2	34.5/13.2
1	Antioquia	-	-	149	10	331	-
2	Boyaca	180	30	125	161	22.5	56
3	Caldas	150	-	470	234	-	254
4	Cauca	-	-	32	67	-	63
5	Cundi-namarca	-	-	-	-	-	79
6	Choco	-	-	18	8	-	-
7	Huila	-	-	88	-	-	79
8	Meta	-	-	55	20	-	17
9	Narino	-	-	28	51	-	57
10	Santander	180	0	246	-	-	229
11	Tolima	-	-	165	20	-	122
12	Risaralda	-	-	-	-	-	20
13	Quindio	-	-	-	-	-	65
14	Putumayo	-	-	-	-	No Data Available	

(Source: Sistema Electrico Del Grupo ICEL 1946-1986)

Table 2.2.8 Future Plan of Transmission Line

Transmission Line	Voltage kV	Length Km	No. of Circuit	Service Year	Electric Company
REMOLINO-HIBPANIA	112	6.3	1	1988	EADE
ORIENTE-LA CEJA (1)	110	16.0	1	1988	EADE
PAIPA-BELENCITO	115	32.0	1	1988	E. Boyaca
CHUGINQUIRA-SIMIJACA	115	14.0	1	1988	E. Boyaca
LOB PALOS-A LA LINEA BARRANCA-B (2)	230	14.6	2	1988	ESSA
POPAYAN-PASTO	230	188.0	2	1988	ICEL
BARRANCA-PALOS (BUCARAMANSA) (3)	230	95.7	1	1989	ESSA
SAN FELIPE, Al CTO ESMERALDA-LA MESA	230	-	-	1989	ICEL
VILLAVIDENCIO-PUERTO LOPEZ	115	85.0	1	1989	ICEL
SANTUARIO-PUERTO RICO	115	75.0	-	1989	ICEL
PASTO-JAMCNDINO (4)	115	6.0	1	1989	ICEL
JAMONDINO-CATAMBUCO (4)	115	18.0	2	1989	ICEL
LA CEJA-SONSON	110	36.0	1	1989	EADE
EL SALTO-EL TIGRE	110	55.0	1	1989	EADE
HISPANIA-JERICO (1)	110	16.8	1	1989	EADE
BOLOMBOLO-BETULIA (1)	110	25.0	1	1989	EADE
PAIPA-SIDERURSICA	115	10.0	1	1989	E. Boyaca
GUADUERO-VILLETA	115	27.0	1	1989	ECSA
MELGAR-FUSAGASUGA	115	35.0	1	1989	ECSA
LIZAMA-SABANA (1)	115	53.0	1	1989	ESSA
FLANDES-MELGAR	115	20.0	1	1989	E. Tolima
PASTO-TUMACO (5)	238	210.0	1	1990	CVC-ICEL
ESMERALDA-HERMOSA (7)	230	22.5	2	1990	CHEC
ALTAMIRA-FLDRENCIA	115	70.0	1	1990	ICEL
VILLAVICENCIO-SRANADA	115	80.0	1	1990	ICEL
BETANIA-ALTAMIRA	115	90.0	1	1990	ICEL
VITERBO-CERTEGUI	115	120.0	1	1990	ICEL
BANADIA-TAME	115	58.0	1	1990	ICEL
TAME-HATO COROZAL	115	34.0	1	1990	ICEL
APARTADO-TURBO	115	20.0	1	1990	EADE
SAN ANTONIO-YOPAL	115	95.0	2	1990	E. Boyaca
ENEA-NORTE (MANIZALES)	115	-	-	1990	CHEC
LA ROSA-LA HERMOSA	115	11.8	1	1990	CHEC
BOTE-SURONIENTE	115	-	-	1990	E. Huila
ALTAMIRA-PITALITO	115	40.0	1	1990	E. Huila
CATAMBUCO-SANDONA	115	28.5	1	1990	CEDENAR
SABANA-SAN ALBERTO (1)	115	-	-	1990	ESSA
PALENQUE-MINAS	115	2.9	2	1990	ESSA
SAN FELIPE-MARIGUITA	115	6.0	1	1990	E. Tolima
FLANDES-ESPINAL	115	5.0	1	1990	E. Tolima
SAN FELIPE-LA SIERRA	115	36.0	1	1990	E. Tolima
PALOS (BUCARAMANGA)-ODANA-MATEO (CUCUTA) (6)	230	222.0	1	1991	ICEL
HISPANIA-ANDES (1)	115	17.0	1	1991	EADE
NORTE-LINEA DORADA	115	3.0	1	1991	CHEC

2.2.5 Electrificating Rate and Generating Cost

Table 2.2.9 shows the electrificating rate by each department in the recent five years (1981 to 1985). Table 2.2.10 shows the change in generating cost by each department.

The electrificating rate in Choco and Cundinamarca departments is around 20%; indicating extremely low.

The average annual increase of electrificating rate in Boyaca and Choco departments is 10% or more, and that of generating cost in Cauca, Caldas, Nariño and Tolima departments is 30% or more. The generating cost in Cauca department is 6.4 Col. $/kWh; indicating the most highest, while that in Antioquia department is most lowest; 3.5 Col. $/kWh, which difference equivalent to about two times as that in Cauca department exists.

Table 2.2.9 Transition of Electrificating Rate (1981-1985)

(Unit: %)

No.	Department	1981	1982	1983	1984	1985	Average Increase Rate
1	Antioquia 1)	34	36	38	43	46	7.9
2	Boyaca	26	27	30	36	39	10.8
3	Caldas	49	51	54	57	59	4.8
4	Cauca	26	27	28	31	33	6.2
5	Cundinamarca	16	17	18	19	21	7.1
6	Choco	10	11	13	15	18	15.9
7	Huila	49	52	54	58	62	6.1
8	Meta	-	33	33	36	39	5.8
9	Nariño	36	38	40	43	45	5.8
10	Santander 2)	44	46	49	53	58	7.2
11	Tolima	40	42	45	48	50	5.8
12	Risaralda 3)	71	72	75	77	79	2.7
13	Quindio 4)	62	64	70	75	79	6.3
14	Putumayo			No Data Available			

1) Teritory of EPM is not included.
2) Teritory of EEEB is not included.
3) Data of EPP
4) Data of CRQ and E. P. de Armenia
(Source: Informe Estadistico Resumen 1981-1985)

Table 2.2.10 Transition of Generating Cost (1981 – 1985)

Table (a) Generating Cost

(Unit: Col. $/kWh)

No.	Department	1981	1982	1983	1984	1985	Average Increase Rate (%)
1	Antioquia	1.72	1.98	2.25	2.73	3.51	19.5
2	Boyaca	1.63	2.05	2.84	2.95	4.16	26.4
3	Caldas	1.27	1.91	2.42	2.67	3.73	30.9
4	Cauca	1.97	2.58	3.30	4.36	6.41	34.3
5	Cundinamarca	2.03	2.67	3.57	4.52	5.68	29.3
6	Choco	2.41	3.23	3.92	4.40	4.17	14.7
7	Huila	1.97	2.90	3.48	4.61	4.94	25.9
8	Meta	-	3.14	4.06	5.03	5.75	22.3
9	Nariño	1.97	3.06	3.84	4.84	5.85	31.3
10	Santander	2.03	3.47	4.30	4.50	5.67	29.3
11	Tolima	1.86	2.44	3.66	4.04	5.63	31.9
12	Risaralda 1)	-	2.01	1.99	-	-	
13	Quindio 2)	-	-	-	-	-	
14	Putumayo			No Data Available			

1) Data of EPP
2) Data of E. P. de Armenia

(Source: Informe Estadistico Resumen 1981-1985)

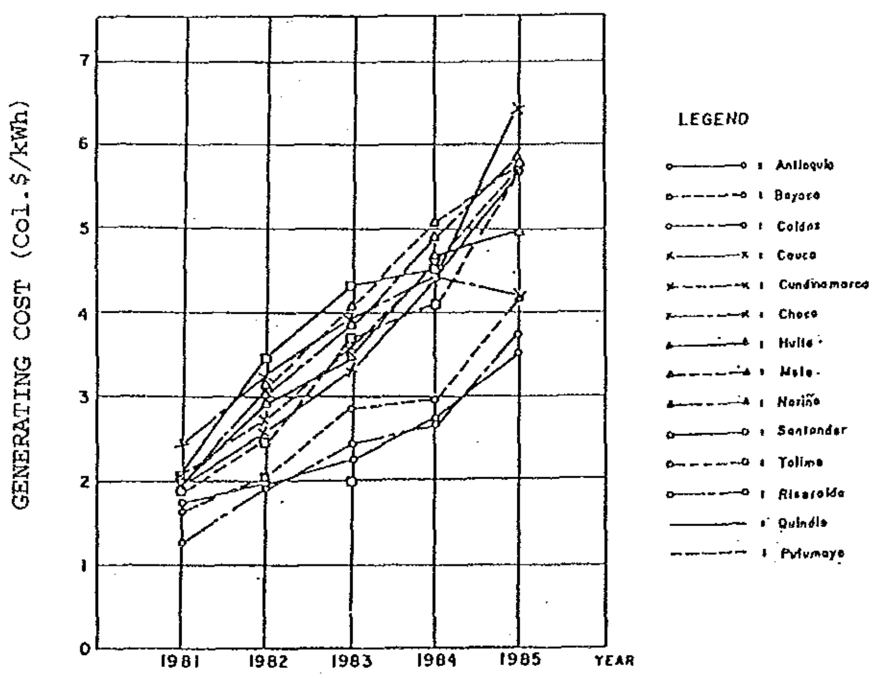


Fig. (a) Increase in Generating Cost

3. Present State of the Study Areas

3. PRESENT STATE OF THE STUDY AREAS

3.1 Classification by Each Power System

The power supply within ICEL group is made through the power system network of ICEL group and Interconnection Electrica SA (ISA). Some study areas are provided with isolated generating facilities which are not connected to those power system networks.

As shown in Table 3.1.1, all the thermal power-generating facilities are connected with the other power system networks, while all the diesel power-generating facilities are isolated power sources separating from the power system networks.

Table 3.1.1 Classification of the Study Area by Power System

Description	Connected to Network		Isolated from Network		Total	
	No. of Power Plant	Installed Capacity (kW)	No. of Power Plant	Installed Capacity (kW)	No. of Power Plant	Installed Capacity (kW)
Thermal Power Plant	3	254,000	-	-	3	254,000
Hydraulic Power Plant	51	185,833	11	6,583	62	192,416
Diesel Power Plant	-	-	17	14,847.5	17	14,847.5
Total	54 (66)	439,833 (95.4)	28 (34)	21,430.5 (4.6)	82 (100)	461,263.5 (100)

Note: Numerical values in ( ) show percentage to total value.

11 power plants isolated from the power system networks in the hydraulic power-generating facilities are shown in Table 3.1.2.

Table 3.1.2 Hydraulic Power Plants Isolated from Power System Network

No.	Power Plant	Electric Company	Installed Capacity (P) (kW)	Available Capacity (Pe) (kW)	Pe/p x 100 (%)	Generator Voltage (kV)	Distribution Voltage (kV)
215	Salamina	E.P. de Salamina	280	140	50	4	4
216	Anserma	E.P. de Anserma					
231	Toribio	CEDELCA	63	35	55	0.23	13.2
233	La Vuelta	E. Choco (Mineros del Choco)	2,000	500	25	4.4	4.4 34.5
234	La Salada	ECSA	280	0	0	4.16	No Use
236	Choachi	E.P. de Choachi	300	19	6	0.38	6.6
237	Apulo	ECSA (Cementos Diamantes S.A.)	3,000	0	0	6.6	34.5
243	El Calvario	EMSA	20	16	80	0.208	0.2
244	San Juanito	EMSA	20	20	100	0.22	13.2
249	Mulato	E.P. de Mocoa	168	0	0	Unknown	
261	Lagunilla	E. Tolima	452	0	0	4.4	No Use
		Total	6,583	730	11.09	-	-

3.2 Present Operating Condition

Some generating facilities in the study areas include generating units which are not operated, which are classified by each power source as shown in Table 3.2.1.

Table 3.2.1 Operating Condition by Power Source in the Study Areas

Operating Condition	Power Plant: Thermal No. of Unit	Power Plant: Thermal Installed Capacity (kW)	Power Plant: Hydraulic No. of Unit	Power Plant: Hydraulic Installed Capacity (kW)	Power Plant: Diesel No. of Unit	Power Plant: Diesel Installed Capacity (kW)	Total No. of Unit	Total Installed Capacity (kW)
Operating	4 (80)	239,000 (94)	77 (62)	159,709 (83)	17 (55)	11,315 (76)	98 (61)	410,024 (80)
Stopping	1 (20)	15,000 (6)	47 (38)	32,707 (17)	14 (45)	3,532.5 (24)	62 (39)	51,239.5 (11)
Total	5 (100)	254,000 (100)	124 (100)	192,416 (100)	31 (100)	14,847.5 (100)	160 (100)	461,263.5 (100)

Note: Numerical values in ( ) show percentage to respective power plant.

(1) Thermal power generating facilities stopped

Among the thermal power generating facilities, #4 unit only of Termopalenque Power Plant is not in operation.

(2) Hydraulic power plants stopped

As of March, 1988, 47 units on 27 hydraulic power plants including those under repair are not in operation, as shown in Table 3.2.2.

Table 3.2.2 Hydraulic Power Plants Stopped

No.	Power Plant	Electric Company	Installed Capacity (kW)	Stopping Unit Installed Year	Type *	No. of Unit
203	Calera	EADE	80	1938	P	1
205	Piedras	EADE	208	1958	F	1
210	P. Guillermo	E. Boyaca	1,280	1963	F	2
214	Guacaica	CHEC	1,120	1929	F	1
219	Santa Rosa	E.P. de Santa Rosa	100	1927	F	1
220	El. Bosque	E.P. de Armenia	2,280	1929	P	1
223	La Union	E.P. de Calarca	1,000	1938	F	1
227	Silvia	CEDELCA	500	1960	F	1
230	Inza	CEDELCA	360	1971	F	1
232	Florida-I	CEDELCA	2,300	1956	F	2
234	La Salada	ECSA	280	1935	F	1
237	Apulo	ECSA	3,000	1928x3 1947x2	T	5
238	La Viciosa	E. Huila	225	1950	F	2
240	Fortalecillas	E. Huila	408	1968	F	1
241	Rio Iquira-I	E. Huila	1,440	1961	P	1
246	Rio Bobo	CEDENAR	4,368	1956	P	3
248	Julio Bravo	CEDENAR	1,500	1942	P	3
249	Mulato	E.P. de Mocoa	168	1964	F	1
251	Zaragoza	ESSA	520	1931	F	1
252	Cascada	ESSA	950	1939x1 1952x2	F	3
253	Comoda	ESSA	880	1912 1954	P.F	4
256	Guali	E. Tolima	1,048	1926x1 1955x2	F	3
257	Rio Recio	E. Tolima	2,000	1960	F	1
258	Mirolindo	E. Tolima	2,400	1946	F	2
259	Pastales	E. Tolima	840	1947	F	1
261	Lagunilla	E. Tolima	452	1940	P	2
262	Ventanas	E. Tolima	3,000	1958	F	1
	Total		32,707			47

* P: Pelton F: Francis T: Tubular

(3) Diesel power plants stopped

As of February 1988, 14 units of 11 diesel power plants including those under repair are stopped and are shown in Table 3.2.3.

Table 3.2.3 Diesel Power Plants Stopped

Code No.	Electric Company	Power Plant	Installed Capacity (kW)	Stopping Unit Intalled Year	Stopping Unit Type	Stopping Unit No. of Unit
301	E. Choco	Acandi	275	1981	Indoor	1
312	E. Choco	Villa Claret	25	1983	Indoor	1
315	E. Choco	Bahia Solano	100	1978	Indoor	1
			140	1972	Indoor	1
321	E. Choco	Nuqui	150	1980	Indoor	1
		Zapzurro	17.5	1958	Indoor	1
337	EMSA	Puerto Lopez	240	1983	Indoor	1
339	EMSA	San Juan de Arama	150	No data	Indoor	1
			145	1971	Indoor	1
341	CEDENAR	Termotumaco	2,000	1965	Outdoor	1
344	CEDENAR	Llorente	120	1971	Indoor	1
345	CEDENAR	Sala Honda	60	No Data	Indoor	1
350	CEDENAR	La Playa	75	1955	Indoor	1
357	CEDENAR	Baquerias	35	1981	Indoor	1
		Total	3,532.5	-	-	14

3.3 Classification of Hydraulic Power Plants by Service Year

Service years of 62 candidate hydraulic power plants for the pre F/S widely range from 2 years (plant constructed in 1986) to 72 years (plant constructed in 1916). Service years are classified into 5 divisions at 10-year intervals as shown in Table 3.3.1. It can be seen from the table that the number of the stopped generating units is increased as the service years become older. 30 to 56% of the power plants with 25 or more service years after installation are not in operation.

Table 3.3.1 Classification of Hydraulic Power Plants by Service Year

Service Years	Operating Condition	Number of Unit	Generating	Total Installed Capacity (kW)	
Below 15	Stop	0	(0)	0	(0)
	Operating	9	(100)	61,340	(100)
	Subtotal	9	(100)	61,340	(100)
16-25	Stop	5	(31)	2,216	(7)
	Operating	12	(69)	29,727	(93)
	Subtotal	17	(100)	31,943	(100)
26-35	Stop	14	(36)	14,676	(30)
	Operating	24	(64)	35,308	(70)
	Subtotal	38	(100)	49,984	(100)
36-45	Stop	9	(35)	5,395	(21)
	Operating	17	(65)	20,874	(79)
	Subtotal	26	(100)	26,269	(100)
Above 46	Stop	19	(56)	10,420	(46)
	Operating	15	(44)	12,460	(54)
	Subtotal	34	(100)	22,880	(100)
Total	Stop	47	(38)	32,707	(17)
	Operating	77	(62)	159,709	(83)
	Subtotal	124	(100)	192,416	(100)

Figures in ( ) show percentage

4. Field Investigation

4. FIELD INVESTIGATION

4.1 Time Schedule

4.1.1 Field Reconnaissance for Thermal Power Plants

The primary field investigation for the following three proposed thermal power plants was conducted from December 2 to December 12, 1987.

- Termopaipa (Electrificadora de Boyaca)
- Termopalenque (Electrificadora de Santander)
- Termobarranca (Electrificardora de Santander)

The secondary reconnaissance for the existing coal ash storage yards for Termopaipa Power Plant which become a problem was carried out on February 26, 1988.

Table 4.1.1 shows the details of field reconnaissance conducted for the proposed thermal power plants.

Table 4.1.1 Field Invesrigation Schedule of Thermal Power Plants

Date	Travel	Visit		Members	
		Electric Company	Power Plant	ICEL	JICA
'87 DEC.2 DEC.3	Bogota → Tunja → Paipa	E. Boyaca	Termopaipa	Augusto Sanabria Diaz	E. Shimomura H. Seto
DEC.4					
DEC.5	Paipa → Bogota				
DEC.7	Bogota → Bucaramanga	ESSA	Termopalenque	Augusto Sanabria Diaz	M. Ono E. Shimomura H. Seto (M. Shibata)
DEC.8			(Meeting)		
'87 DEC.9	Bucaramanga → Barrancabermeja	ESSA	※	Augusto Sanabria Diaz	M. Ono E. Shimomura H. Seto (M. Shibata)
'88 FEB.10	Barrancabermeja → Bucaramanga		Termobarranca		
FEB.24	Bogota → Tunja	E. Boyaca	(Meeting)	Juvenal Peñaloza Victor Pardo	M. Ono E. Shimomura (M. Shibata)
FEB.25	Tunja → PTE. Guillermo		※		
FEB.26	Tunja → Paipa → Bogota		Termopaipa		

Legend AIR
→CAR

※ See Schedule of Hydraulic Power Plant

4.1.2 Field Reconnaissance for Hydraulic Power Plants

Such existing data as questionnaire survey obtained from the electric power companies supplied by the ICEL are reviewed and the field reconnaissance for the proposed hydraulic power plants that are narrowed down was planned to be executed. However, in compliance with the request of the ICEL side, such reconnaissance was executed on 57 power plants except the following five ones:

Power Plants	Reason
No. 216 Anselma (Caldas)	Electric power company has no intention of rehabilitating.
No. 235 Rio Negro (Cundinamarca)	Object of rehabilitation is the improvement of river discharged
No. 249 Mulato (Putumayo)	Both for city water and power generation; Unspecified generating plan; Time restriction because of one point (168 kW) per department.
No. 254 Servita (Santander)	Priority order by electric power company is low.
No. 255 Calichal (Santander)	Priority order by electric power company is low.

The investigation period by department is given below. Table 4.1.2 shows the details of the field reconnaissance done for the proposed hydraulic power plants.

Department	Period		Power Plants
Nariño	Nov. 30 to Dec. 4, 1987	(For 5 days)	4
Santander (Primary)	Dec. 7 to Dec. 12, 1987	(For 6 days)	2
Cauca	Dec. 5 to Dec. 12, 1987	(For 8 days)	9
Cundinamarca	Dec. 15 to Dec. 16, 1987	(For 2 days)	3
Choco	Jan. 25 to Jan. 27, 1988	(For 3 days)	1
Antioquia	Jan. 28 to Feb. 6, 1988	(For 5 days)	9
Caldas, Risaralda	Feb. 8 to Feb. 17, 1988	(For 10 days)	12
Quindio, Meta	Feb. 17 to Feb. 20, 1988	(For 4 days)	2
Boyaca	Feb. 24 to Feb. 26, 1988	(For 3 days)	1
Huila	Feb. 29 to Mar. 3, 1988	(For 4 days)	5
Tolima	Feb. 29 to Mar. 5, 1988	(For 6 days)	7
Santander (Secondary)	Mar. 7 to Mar. 9, 1988	(For 3 days)	2

Table 4.1.2 Field Investigation Schedule of Hydraulic Power Plants (1/3)

Date	Travel	VISIT		MEMBERS	
		Electric Company	Power Plant	ICEL	JICA
'87 NOV.30	Bogota Pasto	CEDENAR	(Meeting)	Jairo Gonzalez	M. Ono Y. Kawasaki M.Tamai (M. Shibata)
DEC.1			Julio Bravo		
2			Rio Bobo, Rio Sapuyes		
3	Pasto → San Pablo		Rio Mayo – II		
4	San Pablo → Pasto		(Meeting)		
5	Pasto → Popayan	CEDELCA	Sajandi	Jairo Gonzalez	Y. Kawasaki M.Tamai
6					
7			(Meeting)Florida- I		
8			Inza		
9			Silvia,Mondomo		
10			Ovejas,Asnazu		
11			Palo, Toribio		
DEC.12	Popayan → Bogota				
DEC.7	Bogota → Bucaramanga	ESSA	(Meeting)	Augusto Sanabria Diaz	M. Ono E. Shimomura H. Seto (M. Shibata)
8			※		
9			Palmas, Zaragoza		
10			※		
11			(Meeting)		
12	Bucaramanga Bogota				
'87 DEC.15	Bogota ⟷ Salada/Apulo	ECSA	La Salada, Apulo	Vicror Pardo	M. Ono E. Shimomura (M. Shibata)
DEC.16	Bogota ⟷ Choachi		Choachi		

LEGEND AIR
→ CAR

※ See Schedule of Thermal Power plant

Table 4.1.2 Field Investigation Schedule of Hydraulic Power Plants (2/3)

Date	Travel	Visit: Electric Company	Visit: Power Plant	ICEL	JICA
'88 JAN.25	Bogota Medellin Quibdo	E.Choco	(Meeting)	Rafael Torres E. Peñuela	M.Ono Y. Kawasaki M. Tamai (M. Shibata)
26			La Vuelta		
27	Quibdo → Medellin		(Meeting)		
28	Medellin → Caracoli	EADE	(Meeting)		
29			Calera, Caracoli		
30	Caracoli → Medellin		La Rebusca		
31					
FEB.1	Medellin → Sonson		(Meeting) Rio Abajo		
2	Sonson → Abejorral		Sonson,Abejoral		
3	Abejorral → Medellin		Piedras		
4	Medellin → Urrao		Tamesis		
5	Urrao → Medellin		Urrao		
6	Medellin Bogota		(Meeting)		
7					
8	Bogota Manizales	CHEC	(Meeting)	Victor Pardo	M. Ono Y. Kawasaki M. Tamai (M. Shibata)
9			Municipal Sancancio, Intermedia		
10			Guacaica, Salamina		
11	Manizales → Pereira		Santa Rosa		
12	Manizales → Pereira		Dos Quebradas, Bel monte		
13			(Meeting)		
14					
15	Manizales → Armenia		Campestre,Bayona La Union		
16	Manizales → Armenia		El Bosque		
17	Manizales → Bogota		(Meeting)		
17	Bogota → Villa Vicencio	EMSA	(Meeting)	Rafael Torres	H. Seto E. Shimomura
18			San Juanito		
19			※		
20	Villa Vicencio → Bogota		El Calvario		
24	Bogota → Tunja	E. Boyaca	(Meeting)	Juvenal Peñaloza Victor Pardo	M. Ono E. Shimomura (M. Shibata)
25			Puenteguillermo		
26	Tunja → Bogota				

LEGEND AIR
→ CAR

※ See Schedule of Diesel Power Plant

Table 4.1.2 Field Investigation Schedule of Hydraulic Power Plants (3/3)

Date	Travel	Visit		Members	
		Electric Company	Power Plant	ICEL	JICA
'88 FEB.29	Bogota → Ibague	E. Tolima	(Meeting)	Jairo Gonzalez	Y. Kawasaki M. Tamai
MAR.1			Mirolindo, Pastales, Ventanas		
2			Rio Recio, Guali		
3			Lagunilla		
4	Ibague → Prado		Prado (Meeting)		
5	Prado → Ibague Bogota		Prado		
FEB.29	Bogota Neiva	E. Huila	(Meeting)	Ilva Lorduy	M. Ono E. Shimomura (M. Shibata)
MAR.1			Rio Iquira – I, II		
2			La Viciosa, La Pita		
3	Neiva Bogota				
4					
5					
6					
7	Bogota Bucaramanga → San Gil	ESSA	Cascada	Victor Pardo	M. Ono E. Shimomura (M. Shibata)
8	San Gil → Comada → Barbosa		Comoda		
MAR.9	Barbosa Bogota				

LEGEND AIR
→ CAR

4.1.3 Field Reconnaissance for Diesel Power Plants

The field reconnaissance was initially scheduled for the proposed 16 diesel power plants, of which four Pizarro, Villa Claret, Sipi and Vista Hermosa power plants were not able to be conducted, because of restraints of natural conditions such as weather, wave, etc. Finally, such reconnaissance was conducted on 13 power plants to which Nuqui power plant were added.

The reconnaissance period by each department is given below and the details of the field reconnaissance are shown in Table 4.1.3.

No.	Period	Department	Power Plants
1	Jan. 25 to Feb. 6, 1988 (For 13 days)	Choco	6
2	Feb. 8 to Feb. 11, 1988 (For 4 days)	Narino	5
3	Feb. 17 to Feb. 20, 1988 (For 4 days)	Meta	2

Table 4.1.3 Field Investigation Schedule of Diesel Power Plants

Date	Travel	Visit		Members	
		Electric Company	Power plant	ICEL	JICA
1988					
JAN.25	Bogota → Medellin				
26	Medellin → Capurgana	E.Choco	Capurgana	Augusto Sanabria dias	H. Seto
27			Zapzurro		E. Shimomura
28	Capurgana Acandi		Acandi		
29	Acandi → Unguia Turbo		Unguia		
30	Turbo → Medellin				
31	Medellin → Bahia Solano El Valle				
FEB.1			Bahia Solano		
2			Bahia Solano		
3	El Valle → Nuqui		Nuqui		
4	Nuqui → El Valle				
5					
6	El Valle → Bahia Solano → Medellin → Bogota				
7					
8	Bogota → Tumaco	CEDENAR	Termo tumaco	Jairo Gonzalez Morales	H. Seto
9			La Playa, Sala Honda		E. Shimomura
10			Baquerias,Llorente		
11	Tumaco → Bogota				
12					
13					
14					
15					
16					
17	Bogota→Villa Vicencio(VV)→Puerto Lopez →VV	EMSA	Puerto Lopez	Rafael Torres	H. Seto
18			*		E. Shimomura
19			San Juan De Arama		
20	VV → El Calvario → Bogota		*		

LEGEND → AIR
→ CAR OR SHIP

※ See Schedule of Hydraulic Power Plant

4.2 Collected Data

The titles of data collected from ICEL and the concerned agencies are listed in Appendix-III) 'List of Collected Data'. Those data thus collected are divided into a) those required for the Pre-F/S and b) those related to the Pre-F/s as mentioned below:

(a) Data required for Pre F/S

1. Result of questionnaire survey on diesel and thermal power plants
2. Result of questionnaire survey on hydraulic power plants
3. Generating facilities register and monitoring record under the control of ICEL
4. Present condition and future improvement plan of the substation facilities and transmission line by system in the candidate power plants for Pre-F/S
5. Record of hydrometeorology observed at areas of the hydraulic power plants

(b) Data related to Pre F/S

1. Publications on the latest energy policy issued by the Ministry of Resource Energy, Economic Planning Agency of Colombia and ICEL
2. Present situation of power demand supply in ICEL and future demand forecast
3. Statistical data concerning the socio-economic situation in the Republic of Colombia
4. Miscellaneous data related to the Pre-F/S

4.3 Summary of Field Investigation Results

The present situations of the power-generating facilities in the candidate power plants for the Pre-F/S are listed on Appendix IV. (Facilities Resister for thermal, hydraulic and diesel power plants)

4.3.1 Thermal Power Plants

The following five units on the following three thermal power plants are candidate one for Pre F/S.

Thermal Power Plant	Unit No.	Installed Capacity (kW)
Termopaipa	#1 unit	33,000
Termopaipa	#2 unit	66,000
Termopaipa	#3 unit	74,000
Termopalenque	#4 gas turbine unit	15,000 (stopped)
Termobarranca	#3 unit	66,000

(1) Termopaipa Thermal Power Plant

This power plant is provided with three coal-burning generating facilities and supplies electric power to the nearest cites and department. It is located in Paipa City whose elevation is 2,500 m. The water of the Chicamocha River is used as a cooling water. Many cities exist in its downstream area. This power plant is also provided with 115 and 230 kV substation and is put under the control of supply demand.

This power plant generally has few automatic operation control system, and the majority of such system is manually operated. In particular, the protection system for boilers and turbines which are main equipment is slightly automated. It is hazardous that such system is operated by the operator's perception, which results in much danger. The rehabilitation or improvement items for this power plant as desired by ICEL are shown in Table 4.3.1.

Table 4.3.1 Items to be Rehabilitated or Improved in Termopaipa Thermal Power Plant

No.	Unit: Installed Year	Unit: Installed Output (kW)	Unit: Available Output (kW)	Items to be Rehabilitated or Improved	Reason
I	1958	33,000	30,000	1) Replacement of air-preheater for boiler	Its efficiency is decreased due to deterioration, so that the frequency of its failure is increased.
				2) Installation of electrostatic precipitator	a. No provision of this device adversely affects the environment. b. Air Pollution Control Law has been established.
II	1974	66,000	66,000	3) Change from pneumatic instrumentation system to electric one	a. Monitoring instrument and automatic control device are either in short supply or do not work properly. b. Procurement of spare parts is difficult.
				4) Increase of turbine output from 66 MW to 74 MW	Output of generator is 74 MW, while that of turbine is 66 MW.
III	1982	74,000	74,000	5) Change of ash handling system	Pressurized conveying system of ash leads to high cost of its maintenance.
Common Problems				6) Ash disposal	Ash from their storage yards flow into the adjacent river, because of insufficient capacity of such storage yard.
				7) Water plant in the cooling ponds	The quantity of cooling water is insufficientand the cost for removing such water plant is high.

(2) Termopalenque Thermal Power Plant

There is a possibility that generator rotor, bearings, etc. except gas turbine are damaged, because the generating facilities for this power plant has not been operated for seven years. Therefore the generator, associated auxiliary equipment, control panel, etc. should be checked.

Table 4.3.2 Items to be Rehabilitated or Improved in Termopalenque Thermal Power Plant

No.	Installed Year	Unit Installed Output (kW)	Unit Available Output (kW)	Items to be Rehabilitated or Improved	Reason
IV	1972	15,000	0	Functional recovery through replacement of gas turbine parts (bearings, blades, etc.)	This unit has not been operated since 1980 because of its failure.

(3) Termobarranca Thermal Power Plant

This power plant is provided with three gas- and oil-burning and one gas turbine generating facilities, and 115/230 kV substation facilities. #3 unit out of four facilities has not been effectively used due to lack of proper cooling water system.

A large oil refinery is located near this power plant. The gases discharged from the refinery have substantially caused corrosion to the equipment installed outdoors, such as boiler.

Table 4.3.3 Items to be Rehabilitated or Improved in Termobarranca Thermal Power Plant

No.	Unit			Items to be Rehabilitated or Improved	Reason or Purpose
	Installed Year	Installed Output (kW)	Available Output (kW)		
III	1978	66,000	40,000	1) Improvement of cooling water system for turbines and genertors (from the existing open type to closed cycle type)	The setting basin is not provided for the intake facilities, so that impurities in the water of the river adversely affect the related facilities.
				2) Installation of an automatic cleaning system for condenser	Turbidity in the water of the river is high and the cooling water system is considerably worn out.
				3) Improvement of direct current supply system	Generator circuit-breaker did not operate, and a high reliability can not be secured because of deteriorated uninterruptive power supply system.
				4) Change from pneumatic instrumentation system to electric one	Difficulty in procurement of these spare parts does not enable the control of combustion and turbine with a high reliability.
				5) Installation of event recorder	It takes a lot of time to investigate the cause of failure occurrence.
Common Problem				6) River revetment works	Erosion by river is encountered, because a long-term counterplan is not considered.

4.3.2 Hydraulic Power Plant

Of the proposed 62 hydraulic power plants, the following five ones are of the reservoir or pondage type and generating facilities are installed in comparatively recent years. The hydrological gauging data, as-built drawings, etc. are kept in constant readiness for reference and the operation, maintenance and control are in a favorable condition.

Table 4.3.4 Reservoir or Pondage Type Power Plants

Code No.	Power Plant	Electric Company	Installed Capacity (kW)	Type	Installed Year
206	Sonson	EADE	3,600	Reservoir	1967
235	Rio Negro	ECSA	9,600	Reservoir	1974
245	Mayo-II	CEDENAR	21,000	Reservoir	1969
250	Palmas	ESSA	18,000	Reservoir	1950/60
260	Rio Prado	E. Tolima	51,000	Pondage	1974

The remaining 57 plants are of the run-of-river type, and generating facilities are generally installed in old years. Such phenomena as shutdown or sharply reduced output are found. In addition, installed capacities are relatively small. 25 plants of 1,000 kW or less (total installed capacity of 11,066 kW) are included.

(1) Property of hydraulic power plant

All of the 62 hydraulic power plants proposed for the Pre-F/S are not possessed by the ICEL group, the following 17 plants are owned by local self-governing bodies (15 plants) and private companies (2 plants).

Table 4.3.5 Hydraulic Power Plants Owned by Local Self-governing Bodies or Private Companies

Code No.	Power Plant	Property	Installed Capacity (kW)	Installed Year	Remarks
208	UrraO	E.P. de Urrao	824	1946	
209	Abejorral	E.P. de Abejorral	724	1960	
215	Salamina	E.P. de Salamina	280	1943	
216	Anserma	E.P. de Anserma	Unknown	Unknown	*
217	Belmonte	E.P. de Pereira	3,760	1941	
218	Dos Quebradas	E.P. de Pereira	8,500	1955	
219	Santa Rosa	E.P. de Sarita Rosa	450	1927	Shutdown
220	El Bosque	E.P. de Armenia	2,280	1929	Shutdown
221	Bayona	E.P. de Calarca	1,008	1952	
222	Campestre	E.P. de Calarca	1,120	1956	
223	La Union	E.P. de Calarca	1,000	1938	Shutdown
233	La Vuelta	Mineros del Choco S.A.	2,000	1916	Private Co.
236	Choachi	E.P. de Choachi	300	1954	
237	Apulo	Cementos Diamates S.A.	3,000	1928/47	Private Co. Shutdown
243	El Calvario	E.P. del Calario	20	1984	
244	San Juanito	E.P. de San Juanito	20	1986	
249	Mulato	E.P. de Mocoa	168	1964	Shutdown

Note: * excluded from the candidate power plants for the Pre-F/S.

(2) Available output and its drop rate

The available outputs of proposed power plants are described in Appendix IV 'Facilities Register'. Generally speaking, the power plant with rated output of 10 MW or less and service life of 21 years or more has a large output-drop rate [(1 - available output/rated output) x 100].

Item	Total Installed Capacity (MW)	Available Output (MW)	Output Drop Rate (%)
Rated output			
10 MW or more	90	84	7
10 MW or less	102.2	40.7	60
Service life			
20 years or less	83.4	76.6	8
20 years or more	108.8	48.1	56

(3) Rehabilitation priority order shown by electric power companies

The priority order of rehabilitation indicated by electric power companies having more than one proposed power plant is given below. As for three departments of Caldas, Risaralda and Quindio, the rehabilitation priority order has not been given by CHEC SA itself, although the Anserma power plant (shutdown for 10 years or longer) was excluded from the area to be studied. The ECSA of Cundinamarca Department is in a similar way.

Table 4.3.6 Priority Order Desired by Electric Power Company

department	Electric Power Company	Priority Order desired by Electric Power Company						
		1	2	3	4	5	6 or less	No Intention
Antioquia	EADE	Sonson	Tamesis	Caracoli	Rio Abajo	Piedras	Rebusca Calera Urrao Abejorral	—
Caldas Risaralda Quindio	CHEC	Electric Power Company has no intention of determining the priority order and comply with such order as determined by JICA.						Anserma
Cauca	CEDELCA	Inza	Silvia	El Palo	Ovejas	Florida – I	Asnazu Toribio Sajandi Hondoso	—
Cundinamarca	ECSA	Electric Power Company has no intention of determining the priority order.						—
Huila	E. Huila	Rio Iquira – I	Rio Iquira – II	La Pita	La Viciosa	—	—	Fortalecillas
Meta	EMSA	El Calvario	San Juanito	—	—	—	—	—
Nariño	CEDENAR	Julio Bravo	Rio Bobo	Mayo-II	Rio Sapuyes	—	—	—
Santander	ESSA	Palmas	Zaragoza	Cascada	Comoda	—	Calichal Servita	—
Tolima	E.Tolima	Pastales	Mirolindo	Lagunilla	Guali	Rio Recio	Ventanas Prado	—

(4) Preparation status of basic data required for rehabilitation plan

a) *Topographic maps*

In order to recognize the locations of power plant sites and its environs, photogrammetric maps (S=1:25,000) published by IGAC, as shown in Table 4.3.7, may be used.

There are not topographic maps of scale 1:5,000 to 1:1,000 which are available to study in more detail. As for the Chinchina valley in Caldas department, aerial photographic of scale 1:10,000 has been arranged for CRAMSA. Therefore, it *may be possible to arrange topographic maps of scale 1:5,000* to 1:1,000 covering the three power plants of San Cancio, Intermidia and Municipal in the same water system.

b) Hydrological gauging data

All hydrological gauging stations located throughout Colombia are listed in HIMAT and the observation records of gauging stations under jurisdiction of HIMAT had been published as annual reports up to 1985.

For 44 hydraulic power plants among the 61 proposed except No. 260 Rio Prado, records of the following 38 hydrological gauging stations are available to make up the flow-duration curve of river flow.

Table 4.3.8 shows the hydrological gauging stations available at each power plant.

Table 4.3.7 IGAC's Photogrammetric Maps (S=1/25,000)

Code No.	Power Plant	River	Code Number of IGAC
201	Caracoli	Nus	132-IV-C
202	La Rebusca	San Roque	132-III-B
203	Calera	Q. Malena	133-III-C, 133-III-O
204	Rio Abajo	Negro	147-II-C
205	Piedras	Piedras	
206	Sonson	Sonson	167-IV-C, 167-IV-D
207	Tamesis	Frio	166-III-D
208	Urrao	Urrao	145-II-B, 147-II-A
209	Abejorral	Q. Yeguas	
210	P. Guillermo	Suarez	170-IV-A
211	San Cancio	Chinchina	206-III-D
212	Intermedia	Chinchina	206-III-B
213	Municipal	Chinchina	206-III-D
214	Guacaica	Guacaica	206-I-D, 206-III-B
215	Salamina	Q. Frisolera	187-III-B
		Q. Palo	
216	Anserma	Deleted	
217	Belmonte	Otun	224-II-C, 224-I-D
218	Dos Quebradas	Otun	224-II-C
219	Santa Rosa	San Eugenio	224-II-C
220	El Bosque	Quindio	243-II-C
221	Bayona	Quindio	243-II-A
222	Campestre	Quindio	243-II-A
223	La Union	Quindio	243-II-A
224	Sajandi	Sajandi	364-III-A
225	El Palo	El Palo	321-I-B
226	Mondomo	Mondomo	
227	Silvia	Piendamo	343-I-D
228	Ovejas	Ovejas	320-IV-B, 320-IV-A, 320-III-B
229	Asnazu	Asnazu	320-II-C
230	Inza	Ullucos	343-IV-B
231	Toribio	Isabelilla	321-IV-A
232	Florida-I	Cauca	342-IV-D

(Cont'd)

Code No.	Power Plant	River	Code Number of IGAC
233	La Vuelta	Andagueda	184-IV-B, 185-III-A
234	La Salada	Bogota	245-II-D
235	Rio Negro	Negro	189-III-A
236	Choachi	Choachi	247-I-C
237	Apulo	Bogota	246-I-A
238	La Viciosa	Q. Viciosa	389-II-C
239	La Pita	Mayo	366-IV-A, 367-III-B
240	Fortalecillas	Fortalecillas	323-II-D
241	Rio Iquira-I	Iquira	344-III-A
242	Rio Iquira-II	Iquira	344-II-A
243	El Calvario	Q. Panela	247-IV-A
244	San Juanito	Guajaro	247-II-C
245	Rio Mayo II	Mayo	411-I-A
246	Rio Bobo	Bobo	429-IV-A
247	Rio Sapuyes	Sapuyes	429-III-C
248	Julio Bravo	Pasto	429-II-A
249	Mulato	Mulato	430-IV-B
250	Palmas	Lebrija	109-IV-C
251	Zaragoza	Surata	109-IV-D
252	Cascada	Fonce	135-IV-A
253	Comoda	Lenguaruco	
254	Servita	Servita	121-IV-C
255	Calichal	Servita	136-II-A
256	Guali (Honda)	Guali	207-II-D
257	Rio Recio	Recio	226-I-D
258	Mirolindo	Combeima	244-II-D
259	Pastales	Combeima	244-II-A
260	Prado	Prado	283-I-D
261	Lagunilla	Lagunilla	226-I-A-1
262	Ventanas	Coello	245-III-D-3, 245-III-D

TABLE 4.3.8 AVAILABLE HYDROLOGICAL GAUGING STATIONS

ELECTRIC COMPANY	Power Plant	GAUGING STATION TO BE USEFUL												
		GAUGING STATION		1	SERVICE IN	2 (km2)	3	4	5	6	7	8	9
		NO.	NAME											
EADE	CARACOLI	2308 – 716	CARAMANTA	01	73 – 07	320	×	×	×	×			
	RIO ABAJO	2308 – 709	RIO ABAJORH-4A	18	63 – 03	–	×	×					
	PIEDRAS	2618 – 707	BOCA TOMA PLTA	18	42 – 04	133	×	×					
	SONSON	2618 – 703	SONSON	01	55 – 06	13	×	×					
	TAMESIS	2617 – 701	PTE. CARRETERA	14	64 – 07	88	×	×					
E.BOYACA	P. GUILLERMO		LA COPETONA	CAR									
CHEC	SAN CANCIO	2615 – 023	BOCA TOMA S. CANC	14	82 – 01		×	×					
	INTERMEDIO	2615 – 023	BOCA TOMA S. CANC	14	82 – 01		×	×					
	MUNICIPAL	2615 – 023	BOCA TOMA S. CANC	14	82 – 01		×	×					
	GUACAICA	2615 – 705	BOCA TOMA	14	68 – 07	150	×						
EPP	BELMONTE	2613 – 711	LA BANANERA	01	63 – 11	198	×	×	×	×		×	
	DOS QUEBRADAS	2613 – 711	LA BANANERA										
EP.de Sta Rosa	SANTA ROSA	2613 – 712	LA REINA	01	71 – 06	156	×	×					
EP.de Armenia	EL BOSQUE	2612 – 701	ALAMBRADO CAICE	01	71 – 09	1309	×	×	×	×		×	
EP.de CALARCA	BAYONA	2612 – 701	ALAMBRADO CAICE										
	CAMPESTRE	2612 – 701	*ALAMBRADO CAICE*										
	LA UNION	2612 – 701	ALAMBRADO CAICE										
CEDELCA	SAJANDI	5201 – 703	FONDALA	01	74 – 06	1846	×	×	×	×		×	
	EL PALO	2604 – 702	BOCATOMA A	01	45 – 08	906	×	×					
	MONDOMO	2602 – 711	TARABITA	01	64 – 09	913	×	×		×			
	SILVIA	2602 – 710	PTE CARRETERA	01	63 – 12	392	×	×					
	OVEJAS	2602 – 728	LOS CAMBULOS	04	81 – 07		×	×					
	INZA	2105 – 704	BOCA TOMA	01	71 – 06	512	×	×					
	FLORIDA – I	2601 – 702	JULUMITO	01	64 – 04	948	×	×	×	×		×	
M. DEL CHOCO	LA VUELTA	1101 – 701	AGUASAL	01	76 – 05	1030	×	×	×	×			
C. DIAMANTE	RIO NEGRO	2306 – 702	COLORADOS	01	52 – 02	3045	×	×	×	×		×	
ECSA	APULO	2120 – 823	TOCAIMA	15	72 – 08	5544	×	×					
E.HUILA	LA VICIOSA	2103 – 701	PTE GARCES	01	64 – 04	969	×	×	×	×		×	
	FORTALECILLAS	2111 – 708	GUAYABO	01	76 – 10	220	×	×	×	×	×	×	×
	RIO IQUILA- I	2108 – 705	BOCA TOMA	01	71 – 07	465	×	×	×	×		×	×
	RIO IQUILA- II	2108 – 705	BOCA TOMA		71 – 07	465	×	×	×	×		×	×
CEDENAR	RIO MAYO- II	5203 – 701	LA CANADA	01	60 – 07	450	×	×	×	×		×	
	JULIO BRAVO	5204 – 701	UNIVERSIDAD	01	70 – 08	177	×	×					
EP.de MOCOA	MULATO	4401 – 701	PIDERA LISAL	01	77 – 10	226	×	×	×	×		×	
ESSA	PALMAS	2319 – 740	ANGOSTURA	01	72 – 08	1865	×	×					
	ZARAGOZA	2319 – 729	CAFE MADRID	01	68 – 12	1284	×	×	×	×		×	
	CASCADA	2402 – 701	SAN GIL	01	55 – 04	1849	×	×	×	×		×	×
E.TOLIMA	GUALI	2301 – 703	PTE LOPEZ	01	71 – 02	1082	×	×					
	RIO RECIO	2125 – 710	LA NUEVA	01	77 – 01	610	×	×	×	×	×	×	
	MIROLINDO	2121 – 726	YULDIMA	01	83 – 06	245	×	×	×	×		×	
	PASTALES	2121 – 723	BOCATOMA	01	83 – 06	12	×	×	×	×		×	×
	LAGUNILLA	2125 – 708	*QUINTA COBRA*	*01*	*72 – 04*	*460*	×	×					
	VENTANAS	2121 – 707	PAYANDE	01	59 – 08	1580	×	×	×	×		×	×

CODE No. OF OPERATOR 01 = HIMAT 18 = EPM (MEDELLIN)
04 = CVC (VALLE DEL CAUCA) 15 = EEEB (BOGOTA)
14 = CHEC (CALDAS)

1 : Code No.of Operator
2 : Catchment Area
3 : Level
4 : Water Volume
5 : Temperature
6 : Sediment
7 : Physical & Chemical Analysis
8 : *Daily Sample of Sediment*
9 : Hydraulic Grade

Most gauging data are recorded as daily flow. However, for 4 gauging station, only the monthly flow has been recorded. As for the following 16 power plants, no hydrological gauging station was found.

Table 4.3.9 Power Plants without Gauging Data

Code No.	Power Plant	Department	River
202	La Rebusca	Antioquia	San Roque
203	Calera	Antioquia	Qd. Malena
208	Urrao	Antioquia	Urrao
209	Abejorral	Antioquia	Qd. Las Yeguas
215	Salamina	Caldas	Qd. Frisolera & Qd. Palo
216	Anserma	Caldas	Qd. Cauya
229	Asnazu	Cauca	Asnazu
231	Toribio	Cauca	Isabelilla
234	La Salada	Cundinamarca	Bogota
236	Choachi	Cundinamarca	Palmar
239	La Pita	Huila	Mayo
243	El Calvario	Meta	Qd. Panelo
244	San Juanito	Meta	Guajaro
246	Rio Bobo	Narino	Bobo
247	Rio Sapuyes	Narino	Sapuyes
253	Comoda	Santander	Lenguaruco
254	Servita	Santander	Servita
255	Calichal	Santander	Servita

c) Record of rainfall

Meteorological stations are distributed and established all over the Colombia under the jurisdiction of HIMAT. Therefore, it is possible to obtain rainfall records required for the F/S. The isohyetal map in the whole Colombia prepared by HIMAT is provided.

d) As-built drawings

As-built drawings of the proposed hydraulic power plants are not stored because they have been scattered or lost for a long term, except for the following 12 power plants.

Code No.	Power Plant	Remarks
201	Caracoli (EADE; Antioquia)	1)
206	Sonson (EADE; Antioquia)	
211	San Cancio (CHEC; Caldas)	
212	Intermedia (CHEC; Caldas)	
213	Municipal (CHEC; Caldas)	
233	La Vuelta (Mineros del Choco S.A.; Choco)	
237	Apulo (Cementos Diamantes S.A.; Cundinamarca)	1)
239	La Pita (E. Huila S.A., Huila)	
241	Rio Iquira-I & II (E. Huila S.A., Huila)	
245	Mayo-II (CEDENAR; Narino)	
250	Palmas (ESSA; Santander)	
260	Rio Prado (E. Tolima S.A.; Tolima)	

1) Partially available

e) Catchment area

Although the catchment area at the intake for a power plant is indispensable to know the flow duration of the river, its data have not been stored.

(5) Present condition of power generating facilities

The facility outline of each hydraulic power plant is listed in the (a) - 2 "Result of questionnaire survey for hydraulic power, plants" in the Appendix III) Collection data and Appendix IV) 'Power Plant Register". General outline of the study is described here.

a) Power generating equipment

For most power-generating facilities have 35 years or more service life. It is difficult to procure spare parts because of its long service life and old type. In the case of power generating equipment with a reduced output or high trouble rate caused by equipment aging, it is very difficult to recover its output up to a rated output through repair works and to maintain the output for a long time. Therefore, such equipment should be replaced with new ones.

In order to replace the power-generating equipment, it is necessary to replace it with the same type or same output unit as much as possible and to account for the standardization of maintain operation control and parts compatibility. In particular, where Pelton type turbine is available together with Francis type, and proper turbine type should be selected.

b) Penstock

Both a long period's use and progress in river-water pollution have so far generated much drilled or cracked portions resulting from wears. For this reason, some power plants are forced to be shutdown for repair works.

Since, for nearly all the run-of-river type hydraulic power plants, the as-built drawings have been scattered and lost, no exact head of fluid can be known.

c) Pressure tank

In most cases, the capacity of a pressure tank contained the run-of-river type hydraulic power plants seems to be too small.

d) Headrace (conduit)

Except for the reservoir or pondage type power plants, almost all the water channels have an open conduit construction. Because the water channels were opened along the topography, they have many poor points with linear, or longitudinal slopes. In addition, their shapes and dimensions are also irregular and few head races keep a good water feeding faculty.

Collapse or small land sliding causes sand and soil to flow into the open channel. In some places, the water channel itself may be in the danger of collapse.

e) Settling basin

Most settling basins have small capacity and the flow velocity within it is so fast that the sedimentation function may be reduced.

f) Intake dam and inlet

Although Tyrolean intakes are partially adopted, the horizontal intake method by means of overflow type intake dam are mainly adopted.

Because of delayed river course rehabilitation works and sand-control works, there are too many bounding stones, gravels, sand and soil flown into. In almost all the intake dams, the sedimentary sand surface reaches up to the top. Therefore, the sedimentary sand face may often be higher than the height of intake floor and moreover the tractive function of a sand discharge gate is restricted to a part. This causes soil and sand to flow into the water channel, which is regarded as a main factor of any worn or damaged water turbine.

g) Gates attached to water channel works

Nearly all the water control gates, sand discharge gates or sand discharge valves are of manual type, and in addition their opening/shutting function is substantially hindered because of their aging or corrosion so that no rehabilitation can be avoided.

4.3.3 Diesel Power Plant

(1) Present condition

Whole proposed power plants (17 areas) are isolated from the power networks system. Except for Termotumaco and Puerto Lopez having a population of 10,000 or above, 15 power plants are minor ones which are established in cities, towns and villages with a population of 5,000 or less, and are scattered in remote areas in Choco, Meta and Nariño departments. Therefore, they are hard to access and their fuel cost is relatively high.

Most diesel engine generators in those minor power plants were moved from other plants before, and no operation manuals have been maintained.

In addition, those power plants are under the jurisdiction of each local self-governing bodies and daily operation time is preset as 5 hours or so. The flat-rate schedule is adopted by each local self-governing bodies.

Therefore, end-users requiring continuous power supply have established a private small diesel generator. Such cases are very often seen in cities. For example, representative users are hospitals, communication facilities, etc. in a public level, and minor commercial or industrial business in a private level.

However, in Termotumaco and Puerto Lopez, electric power is continuously supplied and the meter rate system is adopted for electric charges.

As shown in Table 4.3.10, the power plants not being in operation are 6 units (708 kW) in Choco department, 3 units (535 kW) in Meta department, and 5 units (2,290 kW) in Nariño department; namely 14 units in total (3,533 kW). As shown in Table 4.3.11, some of the main factors of shutdown are regarded as (a) the economical failure due to default in payment and (b) operation stoppage because spare parts of diesel engine and generator are hard to procure. In addition as shown in Table 4.3.12, 64% of the stopped generating facilities have 10 years or longer service life and are considered to need more and more frequent repair.

Table 4.3.10 Inoperative Diesel Power Plant

Department	Power Plant	No. of Units	Installed Capacity (kW)
Choco	Acandi	1	275
Choco	Villa Claret	1	25
Choco	Bahia Solano	2	240
Choco	Nuqui	1	150
Choco	Zapzurro	1	18
Meta	Puerto Lopez	1	240
Meta	S.J. de Arama	2	295
Narino	Termotumaco	1	2,000
Narino	Llorente	1	120
Narino	Sala Honda	1	60
Narino	La Playa	1	75
Narino	Baquerias	1	35
Total		14	3,533

Table 4.3.11 Major Factor of Shutdown

Depart.	No. of Unit	Installed Capacity (kW)	Diesel Engine	Generator	Panels	Other	Under Repair or Study	Economic Problem	Unknown
Choco	6	707.5	1	3	1	1	4	1	1
Meta	3	535	3	0	0	2	1	2	0
Narino	5	2,290	3	1	2	2	4	1	0
Total	14	3,532.5	7	4	3	5	9	4	1

Table 4.3.12 Classification of Diesel Power Plants by Service Life

Depart.	Operation Status	Service Life (Year) 0 - 4	5 - 9	10 - 14	15-	Subtotal	Total
Choco	In operation	1	3	0	0	4	
	Stopped	0	3	1	2	6	10
Meta	In operation	1	0	2	1	4	
	Stopped	0	1	0	4	5	9
NARINO	In operation	4	1	0	4	9	
	Stopped	0	1	0	2	3	12
Total	In operation	6(22)	4(13)	2(6)	5(16)	17(55)	
	Stopped	0(0)	5(16)	1(3)	8(26)	14(45)	31(100)

Figures in ( ) show percentage.

(2) Future program

As an example of alternative measures to a diesel power plant whose power supply is more unstable compared with any other power source, a plan has been started that the diesel power plants are connected to the electric power networks in Meta and Nariño departments and a minor hydraulic power plant is under construction in Choco department. The outline of such plans is as follows:

1) Between Puerto Lopez and Villa Vicencio (in Meta Department)
Transmission line (34.5 kV x 1 circuit):
To be completed in 1989

2) Between Tumaco and Pasto (in Narino Department)
Transmission line (230 kV x 1 circuit):
To be completed in 1991

3) Bahia Solano (in Choco Department)
Mini-hydro power plant (2.4 MW):
To be completed in 1990

5. Rehabilitation Plan of Thermal Power Plants

5. REHABILITATION PLAN OF THERMAL POWER PLANTS

5.1 Solution to Improvement Items

Solutions to items for rehabilitation or improvement of the following power plants desired by ICEL are described by each power plant.

5.1.1 Termopaipa Power Plant

The common item for the rehabilitation or improvement of this power plant is to change from pneumatic instrumentation system for #1 and #2 unit to electric system.

The most important items are to increase the output of turbine for #2 unit from 66 MW to 74 MW and secure a sufficient space for ash storage yards, which are likely to be filled up in the near future.

Rehabilitation or Improvement Items	Solutions
(1) Replacement of air-preheater for boiler (#1 unit)	1) A proper type of such preheater is selected from among one tublar, separate tublar or rotary type.
	2) The strength on the existing supporting structures shall be studied.
(2) Installation of electro-static precipitator (#1 unit)	1) As there is no available space to install this precipitator between existing boiler and chimney, the general arrangement including relocation or modification of the various facilities adjacent to that area shall be studied to install this precipitator.

(cont'd)

Rehabilitation or Improvement Items	Solutions
(3) Change from pneumatic instrumentation system to electric one (#1 unit -- Supervisory instrumentation and automatic control device are lacking.)	1) The lacking supervisory instrumentation and automatic control device shall be decided under consultation with the existing turbine and boiler manufactures. Detectors attached to turbine and boiler shall be installed by respective manufactures.
(#2 unit -- The boiler control system does not function since the start of commercial operation)	2) The cause for malfunction of automatic boiler-controlling system for #2 unit shall be investigated and rehabilitated.
	3) The change instrumentation system from pneumatic to electric one requires mainly the replacement, modification and addition, as mentioned below: - Replacement of transducer - Modification of air piping - Addition of control power supply system - Cabling - Addition and new installation of relay, power supply and control panels The present condition of air piping shall be checked.

(cont'd)

Rehabilitation or Improvement Items	Solutions
	Terminal points for control power supply system, space for cabling and spaces for the installation of relay, control and battery panels shall be studied.
(4) Increase of turbine output (#2 unit, from 66 MW to 74 MW)	1) The plan for modification of turbine itself and auxiliary equipment such as feed water heater shall be formulated by consultation with supplier of existing machines.
(5) Change of ash disposal system (#3 unit -- its maintenance cost is high.	1) The same style conveyor system as that in #1 and #2 unit shall be provided considering operation, maintenance, etc.
(6) Ash disposal problem	
(a) No more capacity in ash storage yards	1) To purchase new land for ash disposal
	2) To change to a closed-cycle cooling system employing a cooling tower as an alternative plan, and use the existing cooling pond as ash storage yard.
(b) Ash flows from ash yard into the adjacent river	3) To provide wall for preventing ash from outflow on both banks of the river.

(cont'd)

Rehabilitation or Improvement Items	Solutions
	4) The rain water within the ash storage yard shall be drained into the river after being purified through filter and sedimentation basins to be installed.
(c) Alternative plan for ash disposal by truck	5) There are three methods for hauling ash using belt conveyor, pressurized water or vacuum. These three methods shall be compared from the economical point of view.
(d) Effective use of ash	6) Practical application of ash includes materials for site preparation for landfill and road. Fly ash can be used as cement admixtures, but a market research shall be conducted in that case.
(7) Removal of Water Plant in the cooling ponds	1) To remove water plant using aquatic harvester 2) This problem can be solved according to the above item (6)-2).

5.1.2 Termopalenque Power Plant

An indoor-type gas turbine generating unit, which was installed in 1971 and has been operated since 1972, should be rehabilitated.

The outline of such gas turbine generating unit is as follows:

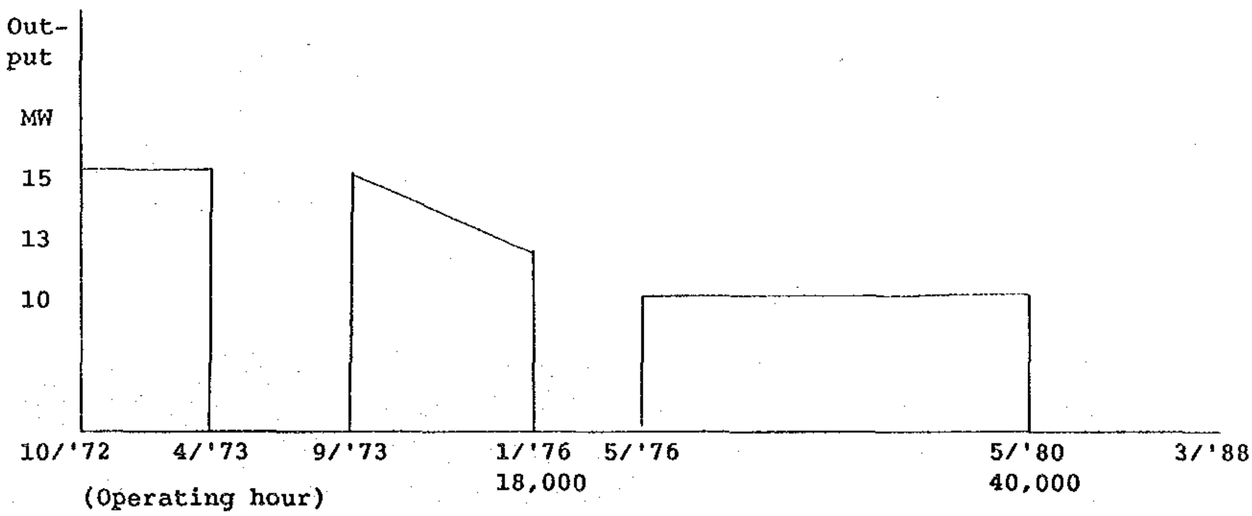
Manufacturer	:	Westinghouse, U.S.A.
- Type	:	W-191G
- Condition of inlet	:	77°F/1361 PSIG
- Air flow	:	24,216 ℓ/sec
- Revolution	:	4,912 rpm
Generator		
- Type	:	HG 75 1/2
- Capacity	:	19,200 kVA
- Revolution	:	900 rpm
- Power factor	:	0.85
- Voltage	:	13,800 V
- Frequency	:	60 Hz

The following repair works were executed by Westinghouse/ESSA. The operation was suspended in 1980 due to an accident caused by vibration in the turbine axis.

(1) Apr. - Sept. 1973: Repair of defective turbine blades

(2) Jan. - May 1976: Repair of bearing and supports for turbine (the generating unit after repair work has been operated at the output of 10 MW until May 1980)

The operation period/output is shown in the following figure.



This power plant is provided with five gas turbine power generating equipment of #1 unit through #5 unit. However, #1 and #2 units have been removed and only #3 and #5 units are in operation.

Service life of #4 unit after installation was 15 years. During that period, #4 unit had been in operation for seven years and five months. This unit has been suspended for eight years since May 1980.

The rehabilitation or improvement of #4 unit was studied and its detail is as follows:

Items for Rehabilitation or Improvement	Proposed Solutions
Replacement of gas turbine parts such as blades and bearing	(1) ICEL/ESSA requests the supplier of the existing unit to study the possibility of replacement. (Review of proposal in 1983) (2) To study the alternative plan to replace the existing gas turbine, generator and all the auxiliary equipment with new ones, leaving the fuel gas feed system and sound-proof house untouched. (3) To technically and economically evaluate the priority order, after making a comparative study of the results of the above items (1) and (2).

The existing gas turbine is obsolete, and is partially remodelled by the manufacturer. If parts are partially replaced, any other portions not repaired or replaced are expected to be damaged.
As described in the above Solution (3), it is, therefore, recommended to make a comparative study with an alternative plan.

5.1.3 Termobarranca Power Plant

The major problem to be solved for the existing generating facilities is that generating equipment are worn out by sand contained in cooling water, which consequently causes drops in the efficiency of machinery.

Cooling water is taken from Rio Magdelena. As no settling basin is provided between the river and circulating water pump station, the cooling water is led directly from the river to screen and pump.

Therefore, the following solution for the above problem is considered.

(1) Improvement of cooling system (oil cooler for turbine and air cooler for generator)

(2) Installation of an automatic condenser-cleaning system

(3) New construction of settling basin

The proposed common rehabilitation items is the change from pneumatic instrumentation system to electric one.

The following solutions was proposed for the request to be rehabilitated or improved on this power plant.

Items for Rehabilitation or Improvement	Proposed Solutions
(1) Improvement of cooling water system (oil cooler for turbine and air cooler for generator)	1) To install a double strainer immediately after being branched from the water pipe for condenser for primary cooling water system to change to closed-cycle one.

(cont'd)

Items for Rehabilitation or Improvement	Proposed Solutions
(2) Installation of the automatic condenser-cleaning system	1) To modify a part of the condenser chambers to install automatic changeover valves. With the automatic opening/closing operation of the valves, the direction of the water flow within the condenser will be reversed to clean the condenser.
	2) To study as to how degree turbidity of the cooling water is decreased by modifying the cooling water intake and constructing the settling basin.
(3) Improvement of DC supply system	1) To determine the backup supply system by reviewing the entire system and uninterruptive power supply, and making a comparative study on the common system and secure the system with high reliability.
(4) Change from pneumatic instrumentation system to electric one	1) The cause for malfunction of the control system shall be investigated for the rehabilitation.
	2) The change instrumentation system from pneumatic to electric one requires mainly the replacement, modification and addition, as mentioned below:

(cont'd)

Items for Rehabilitation or Improvement	Proposed Solutions
	- Replacement of transducer - Modification of air piping - Addition of control power supply system - Cabling - Addition and new installation of relay, power supply and control panels The present condition of air piping shall be checked. Terminal points for control power supply system, space for cabling and spaces for the transportation and installation of relay, control and battery panels shall be studied.
(5) Installation of event recorder	1) Basic items to be recorded by public electric power companies within ICEL group which own thermal power plants shall be determined, and information shall be exchanged between thermal power plants for more reliable operation.
(6) River revetment works	1) To execute permanent revetment works.

5.2 Technical Study of Proposed System and Equipment for Rehabilitation

Rehabilitation and replacement of the system as previously proposed as solutions for rehabilitation or improvement are roughly studied as follows:

5.2.1 Rehabilitation plan of Termopaipa Power Plant

(1) Type selection of boiler air-preheater (#1 unit)

1) The existing air-preheater is of one tubular type. As shown in Table 5.2.1, the rotary type one is recommended as a result of comparative study with other types.

Table 5.2.1 Comparison of Air-preheaters

	Item	One Tubular	Separate Tubular	Rotary
1	Thermal efficiency	8	8	10
2	Ease of operation and maintenance	8	8	10
3	Economic efficiency of operation and maintenance	10	9	8
4	Pressure loss in gas/air	7	7	10
5	Installation space	7	5	10
6	Modifying cost of existing structures	10	3	10
7	Ease of installation works	8	7	10
8	Equipment cost	7	5	10
9	Installation work cost	8	6	10
	Total evaluation	73	58	88

As a result of the above evaluation, its ranking is as follows:

1) Rotary type
2) One tubular type
3) Separate tubular type

2) Problems on rehabilitation

The existing air-preheater is of one tubular type and is supported by structural steels. At the removal of the existing air-preheater, the installation and erection of a new preheater, it is necessary to remove a part of the supporting structures. The strength of the structural steels supported should be examined.

3) Outline specifications of air-preheater

- Type	;	Rotary type
- Gas volume	;	Inlet 214,000 kg/hr
		Outlet 235,600 kg/hr
- Gas temperature	;	Inlet ; 350°C, Outlet ; 150°C
- Air volume	;	Inlet 204,600 kg/hr
		Outlet 183,000 kg/hr
- Air temperature	;	Inlet ; 20°C, Outlet ; 266°C
- Number of units	;	one unit

(2) Installation of electrostatic precipitator

1) An electrostatic precipitator shall be newly installed for #1 unit.

(i) There is a narrow space between the existing boiler and smokestack. Around there, there are coal conveyor, water treatment plant for boiler, etc. which are commonly used in #1, #2 and #3 units.

As shown in Fig. 5.2.1, new installation of electrostatic precipitator would entail the improvement work such as the removal and new construction of smokestock, etc.

(ii) With the installation of the electrostatic precipitator, the air pressure should be increased by a forced draft fan. Therefore, the existing capacity of forced draft fan should be increased.

(iii) With the replacement of an air-preheater and the installation of the electrostatic precipitator, ducts should be newly installed to connect to the forced draft fan, boiler, electrostatic precipitator and smokestack.

2) Outline specifications of electrostatic precipitator

- Gas volume	;	137,000 Nm^3/hr
- Gas temperature	;	150°C
- Dust density	;	Inlet/Outlet 26.5/0.35 g/m^3
- Dust collecting efficiency	;	99.4%
- Number of units	;	one unit

3) Outline specifications of forced draft fan

		Max. continuous	Rating
- Air volume	;	56,000 Nm^3/hr	70,000 Nm^3/hr
- Actual air volume under the site condition (27°C/ 555 mmHg)		84,5000 m^3/hr	107,000 m^3/hr
- Forced pressure	;	800 mmAq	1,000 mmAq
- Number of units	;	one unit	

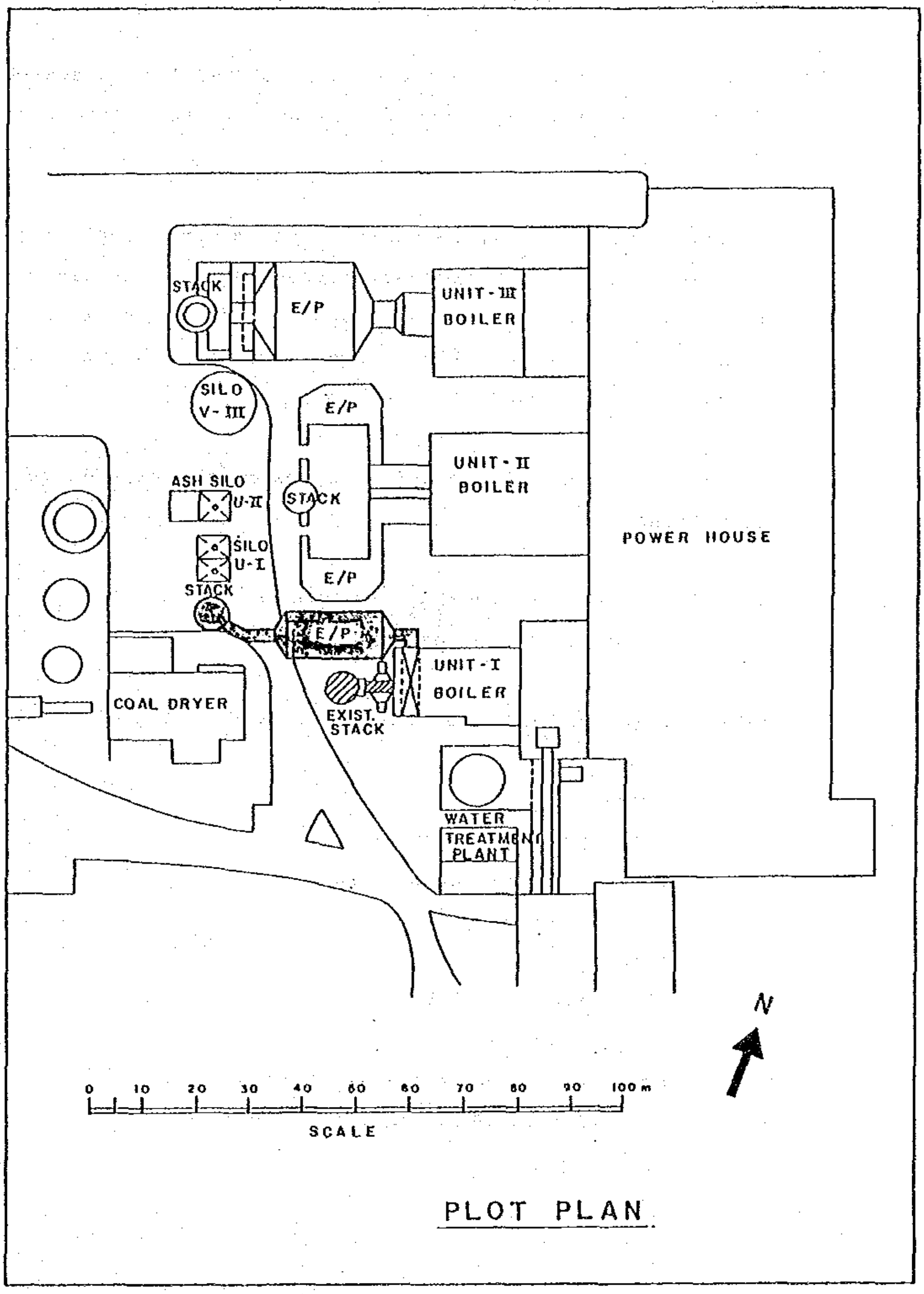


Fig. 5.2.1 General Plot Plan

(3) Replacement plan of instrumentation system (#1 and #2 units)

1) Change from the existing pneumatic instrumentation system to electric one (data and specifications for the system were not obtained.)

As described in 5.1.1, to replace the instrumentation system, the replacement of transducer, improvement of air pipings, additional power source, additional installation of various panels, panels installation space, etc. shall be studied to change the instrumentation system.

The manufacturers of the existing instrumentation devices are as follows:

#1 unit: Bailey, France

#2 unit: Turbine; Yamatake Honeywell, Japan

Boiler ; Bailey, USA

2) Major items for instrumentation and study added to #1 unit

(i) Boiler

- Ignition and burner control
- Control of combustion equipment
- Water level control
- Water feed control
- Steam flow control
- Temperature control
- Detection of pressure in furnace
- Detection of pressure and air volume
- Protection of boiler

(ii) Turbine

- Supervisory panel
- Vibrometer
- Eccentricity indicator
- Metal thermometer
- Shaft position indicator
- Bearing thermometer
- Manual/automatic changeover control

(iii) Common equipment

- Replacement of transmitters
- Additional power source
- Installation of relays and control panels
- Modification of the existing air pipings

3) Replacement of combustion equipment for #2 unit

The combustion equipment should be replaced with a new one because its automatic control device for boiler combustion does not function since the start of the commercial operation. (Existing data and specifications were not obtained.)

(4) Improvement plan for output increase of #2 unit

This plan is to increase the turbine output from 66 MW to 74 MW by replacing the turbine and feed water heater.
In this regard, one turbine manufacturer submitted a proposal in September, 1987.
The major equipment or device to be replaced are as follows:

1) Turbine

- Turbine rotor
- Turbine blades
  (1st stage to 16th stage)
- Nozzle and diaphram
  (1st stage to 16th stage)
- Governor and main oil pump driving expansion shaft

The state of which parts to be replaced are mounted is shown in Figs. 5.2.2 and 5.2.3.

2) Feed water heater
   - A set of No. 1 low pressure feed water heater
   - A set of No. 2 low pressure feed water heater
   - A set of No. 4 high pressure feed water heater

These specifications are shown in Fig. 5.2.4 and Table 5.2.2.

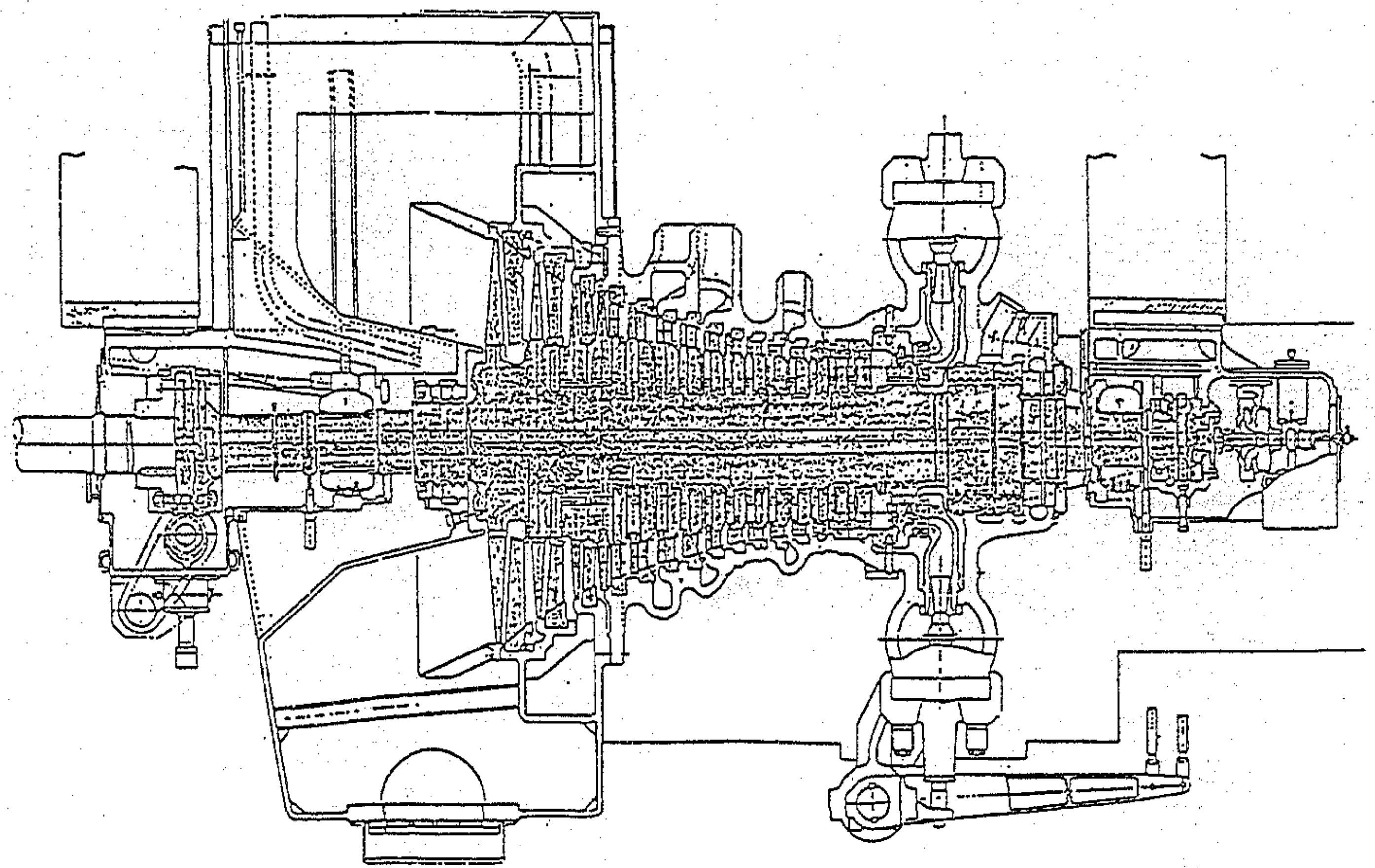


Fig. 5.2.2 Explanatory Drawing of Replacement Part for Increasing Turbine Output (Replace the Part of ▭)
(Termopaipa #2 unit)

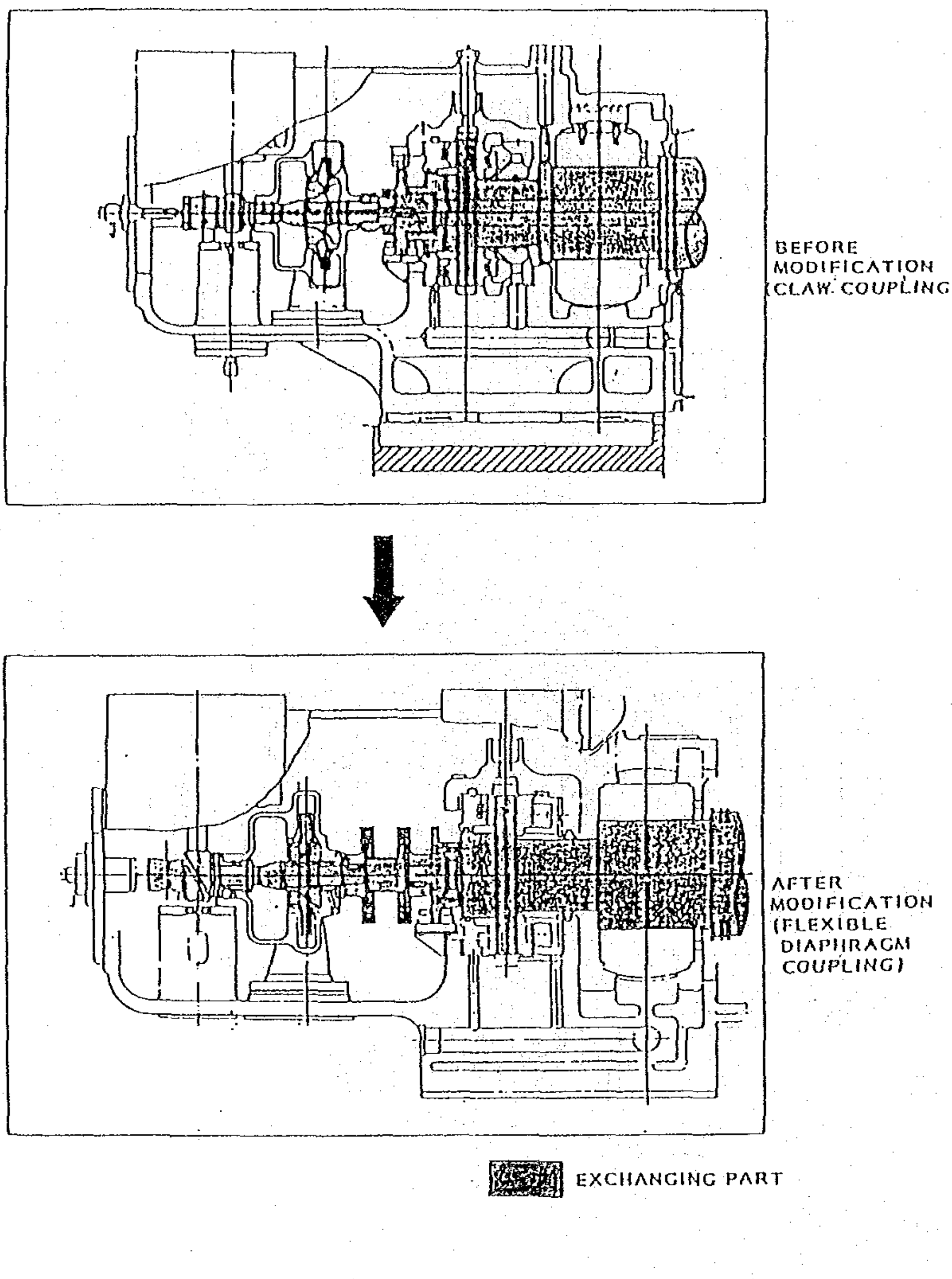


Fig. 5.2.3 Explanatory Drawing of Shaft Expansion(Termopaipa #2 unit)

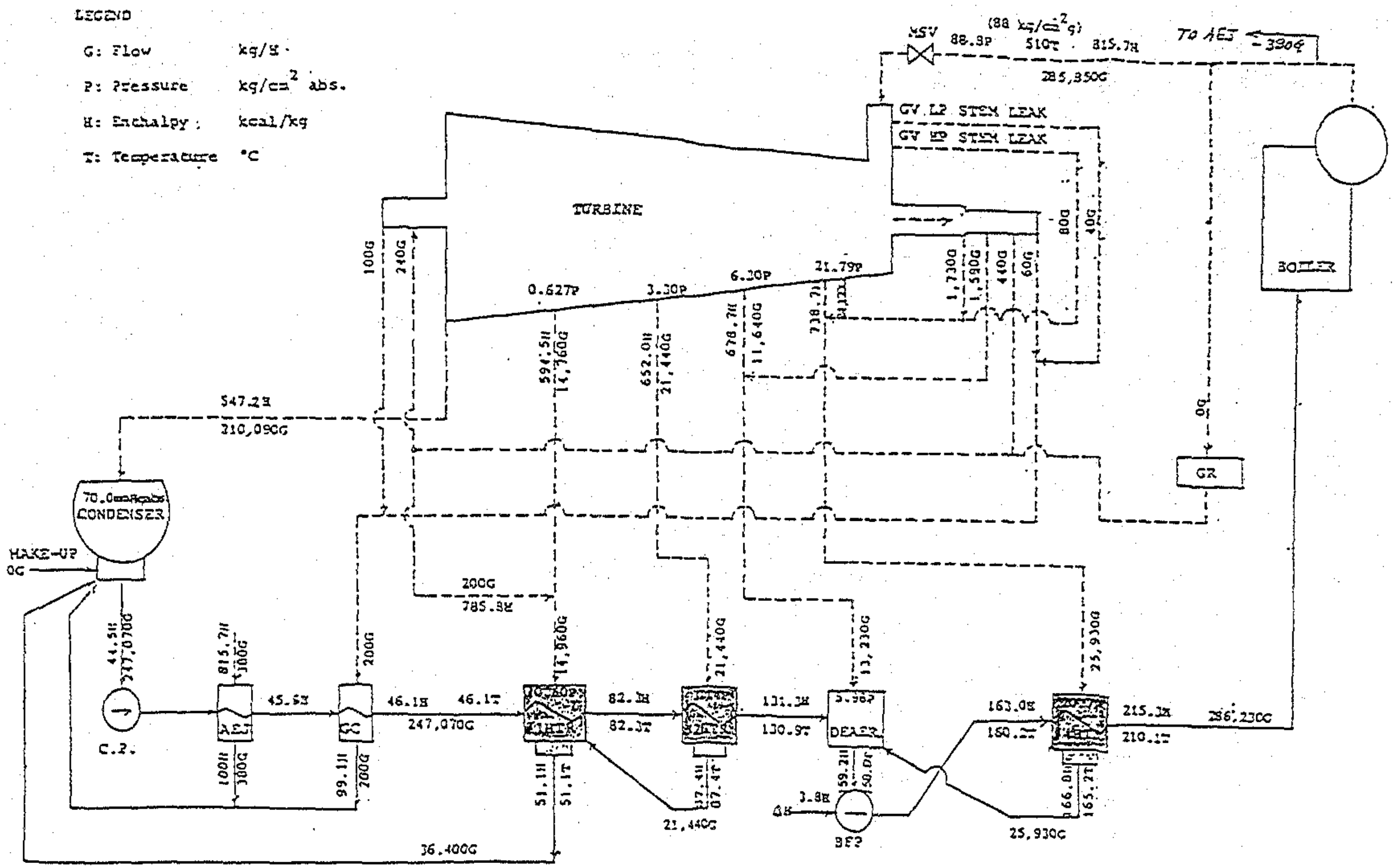


Fig. 5.2.4 Heat Balance (Termopaipa #2 unit)

Table 5.2.2 Comparison of Feedwater Heaters

Heater No.	Items	Unit	Current Spec. 66,000 kW	Spec. after Improvement 74,000 kW
LP NO. 1 Heater	Heating surface area	m^2	240	281
	Number of tubes		U-230	U-265
	Shell I.D.	mm	750	800
	Channel I.D.	mm	750	800
	Total length	mm	11,800	12,100
LP NO. 2 Heater	Heating surface area	m^2	200	221
	Number of tubes		U-230	U-265
	Shell I.D.	mm	750	800
	Channel I.D.	mm	750	800
	Total length	mm	10,000	9,750
HP NO. 4 Heater	Heating surface area	m^2	260	300
	Number of tubes		U-342	U-394
	Shell I.D.	mm	860	1,140
	Channel I.D.	mm	750	1,030
	Total length	mm	8,920	9,020

(5) Change of ash-conveying system for #3 unit

The ash-conveying system should be changed from slurry system to belt conveyor system which is the same as that used for #1 and #2 units, because of its high maintenance cost and easy procurement of parts. The conveyor layout plans are shown in Figs. 5.2.5, 5.2.6 and 5.2.7. The outline specifications of conveyor are as follows:

- Conveying capacity : 5.5 ton/h
- Conveyor total length: Approx. 100 m

(6) Cooling system by use of cooling tower (Closed cycle system)

To solve the capacity shortage of the existing ash storage yard, the existing cooling pond is to be available as a new alternative ash storage yard. In stead of the existing cooling pond, a cooling tower should be installed to operate the cooling system in a closed cycle. The change of cooling system requires a new installation of the cooling tower and the change of cooling water supply/discharge system. The improvement plan of the cooling water system is shown in Fig. 5.2.8 and the layout plan of the cooling tower is shown in Fig. 5.2.9.

The outline specifications of the equipment to be newly installed or replaced in the change of the cooling system are as follows:

1) Specifications of cooling tower

- Capacity	19,000 ton/h
- Cooling water temperature	Inlet 38°C
	Outlet 30°C
- Ambient temperature	20 to 28°C
- Number of units	2 units

2) Outline specifications of circulating water pumps

If the cooling water system has been changed, the pump head of existing circulating water pumps will be insufficient and such pumps needs be replaced with ones as specified below:

	(Capacity)		(Head)		(No. of units)
For #1 unit	6,500 m^3/h	x	32 m	x	2 units
For #2 unit	12,200 m^3/h	x	30 m	x	2 units
For #3 unit	12,200 m^3/h	x	30 m	x	2 units

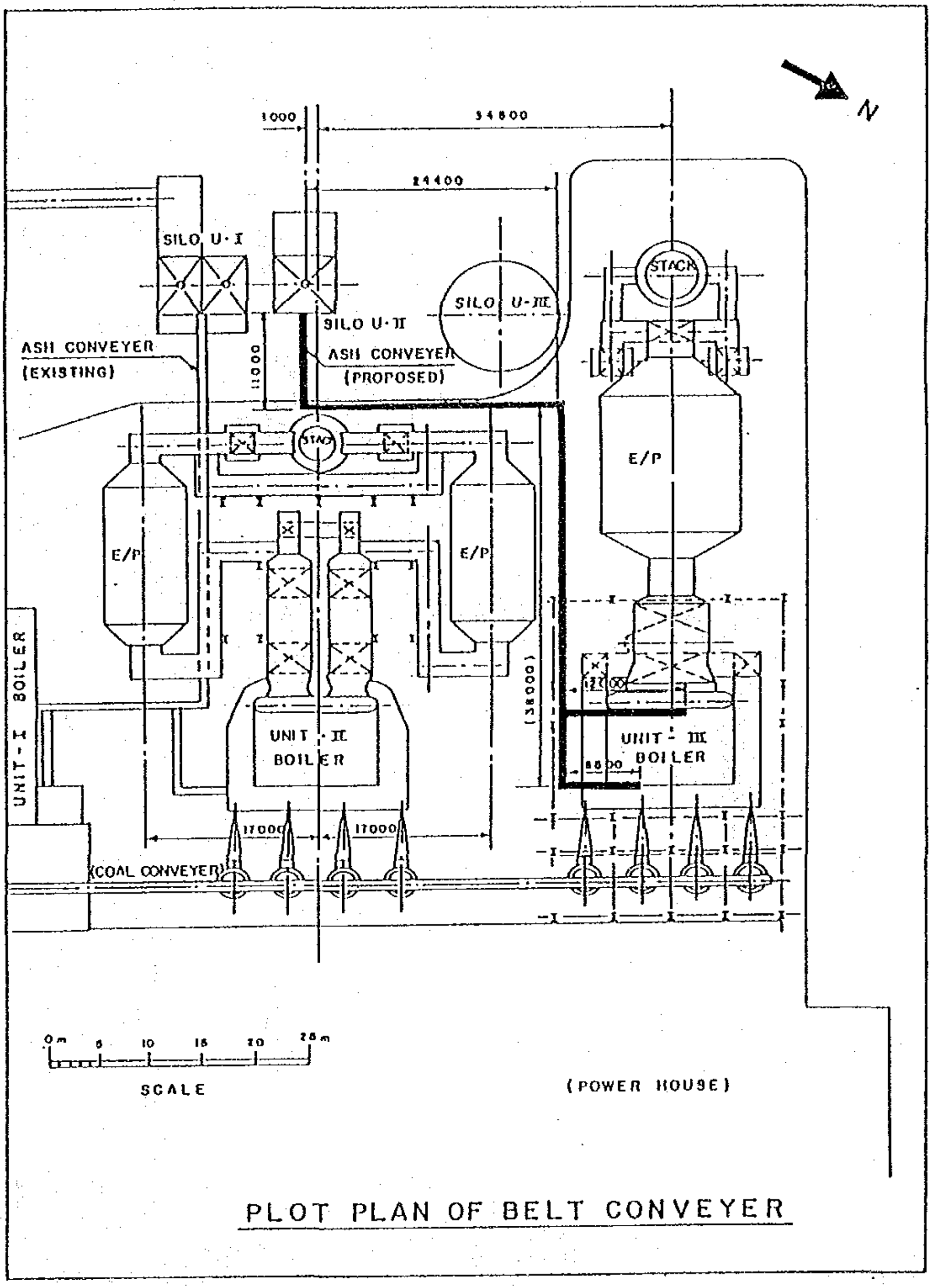


Fig. 5.2.5 Conveyor Layout (Plan view)
(Termopaipa #3 unit)

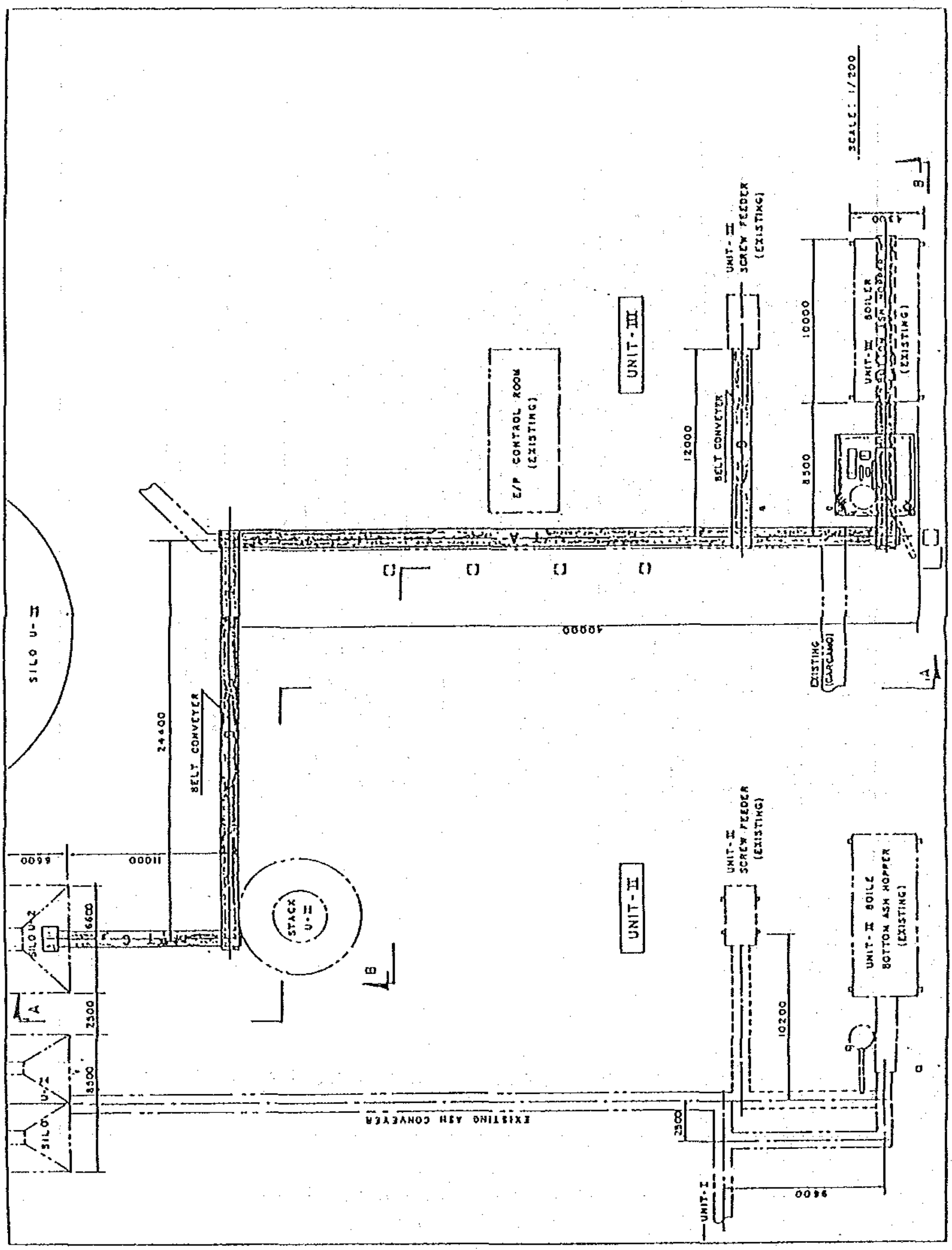


Fig. 5.2.6 Conveyor Path Layout (Plan view)

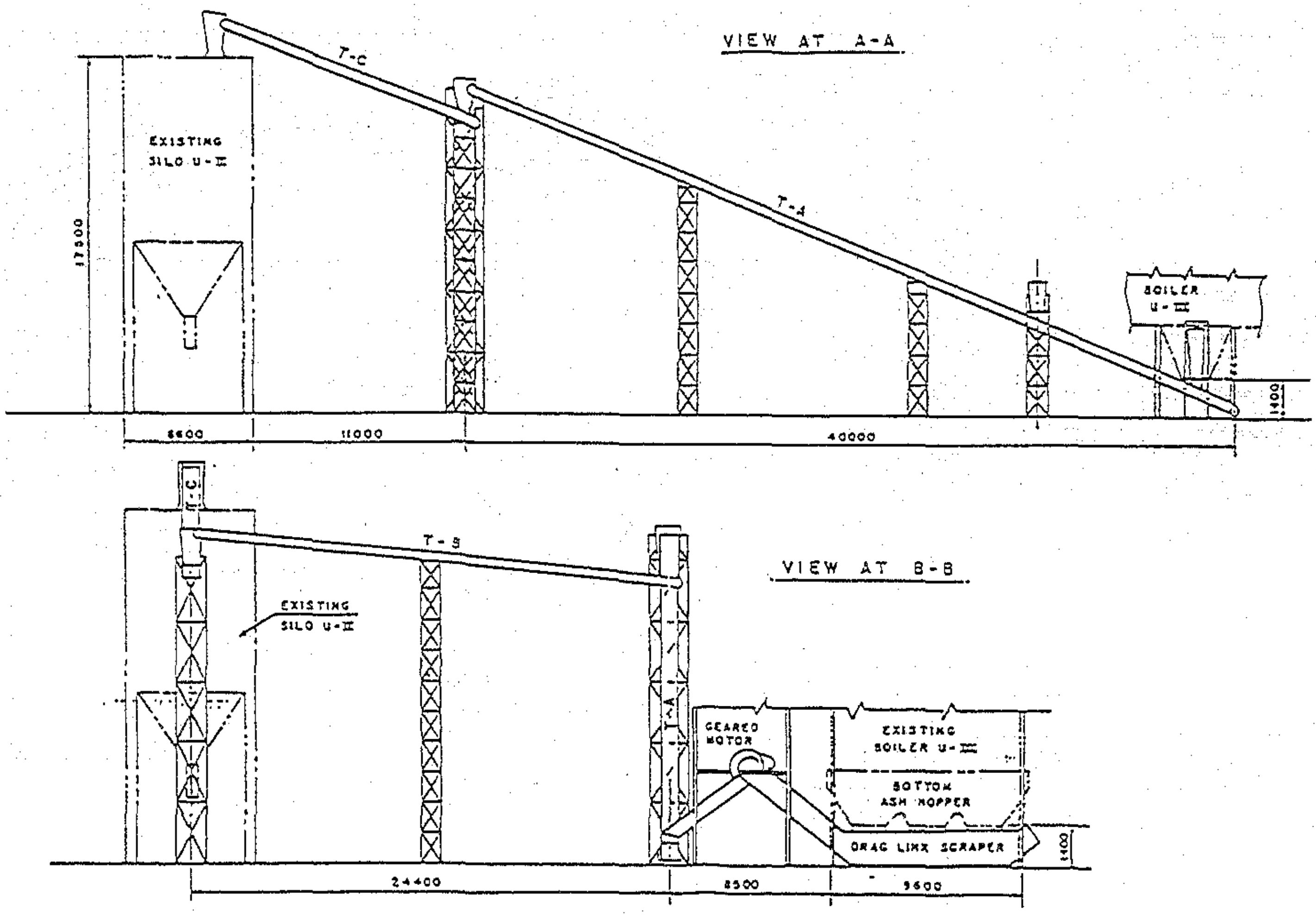


Fig. 5.2.7 Conveyor Path Layout (Side view)

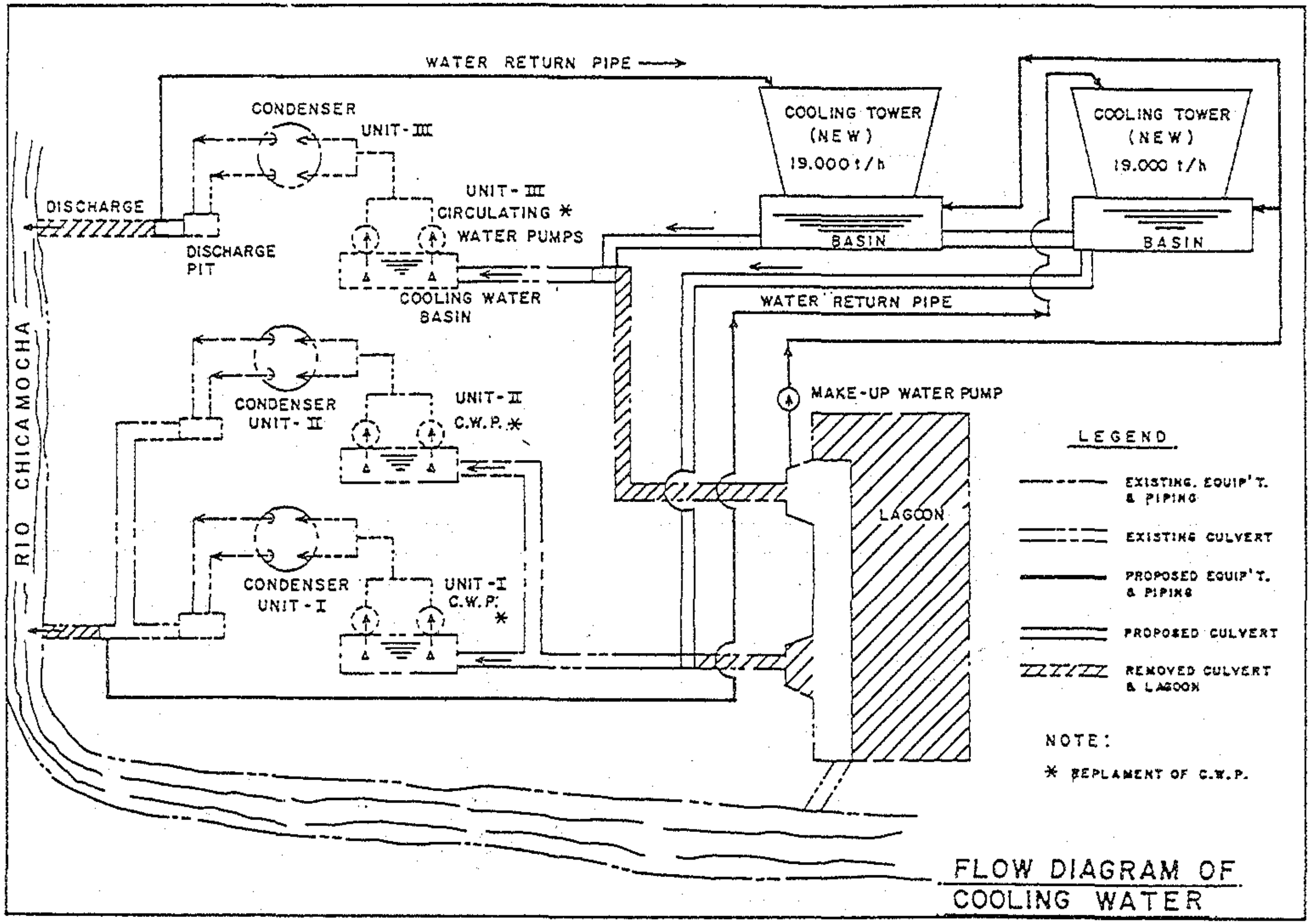


Fig. 5.2.8 Cooling Water System Drawing

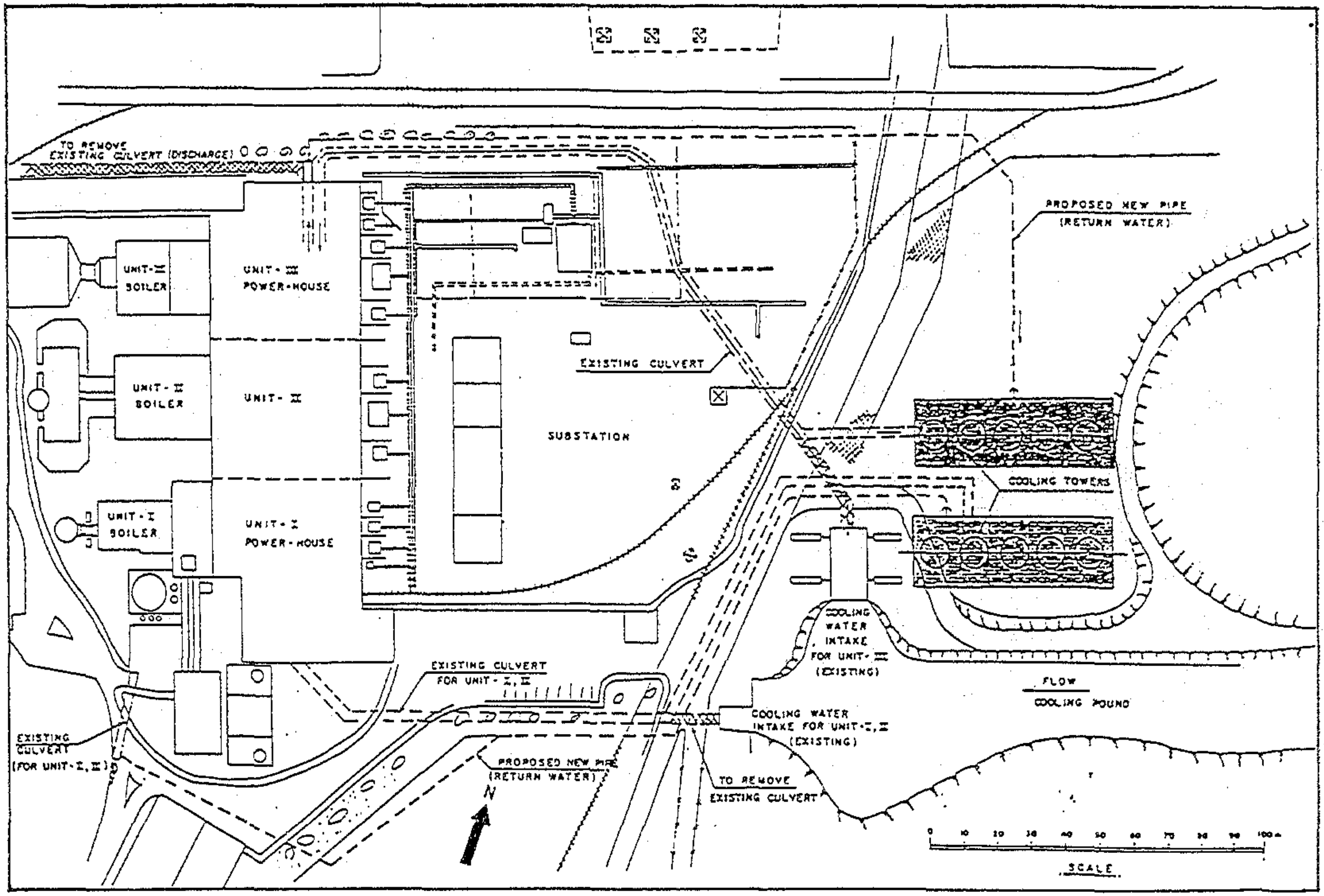


Fig. 5.2.9 Layout of Cooling Tower
(Termopaipa)

(7) Measures to reduce the volume of ash discharged through effective utilization of the coal ash

Approx. 256-ton ash is discharged daily from Termopaipa thermal power plant. However, as described above, as there is little space available for the existing ash storage yard, it has been tried to reduce the volume of discharged ash through effective utilization of the coal ash.

There are many examples in advanced countries for the utilization method of ash discharged from the thermal power plant. However, as shown in Table 5.2.3 (a), the utilization factor is as small as 20 to 55%, most of which is indeed used for landfill. For reference, some utilization examples of coal ash are introduced in Table 5.2.3 (b).

Table 5.2.3 How to Use Coal Ash

(a) State of Ash Utilization

Year	U.K. 1977	France 1977	Germany 1976	USA 1976	Japan 1983
Total yield	12,336 kt	4,828 kt	4,374 kt	61,900 kt	3,424 kt
Used ash volume	5,070	2,006	2,413	12,400	1,255
(Utilization factor)	41.1%	41.5%	55.1%	20.0%	35.8%
Purpose of used ash (%)					
Cement mix	0.6	42.7	6.4	5.2	11.0
Cement material		19.6			
For concrete	2.5		12.9	7.3	1.5
		0.3	9.7	Blick	
For road	36.7	23.9	8.2	22.9	8.2
For spray			11.1	9.8	
Concrete block	11.8				
For grouting	2.8				
For filling	8.1				
Artificial lightweight aggregate	6			1.6	
For snow and ice control				4.5	0.2
Clinker sales	9.1				
Miscellaneous	20.4	4.3	51.7	13.1	7.0
Landfill		9.2			64.0
Use after disposal Grant				22.7	
To facilities				12.1	
Total	100%	100%	100%	100%	100%

Note: Many % for roads.
Possessive use for cement. Also standardized for roads.
*1 Excluding landfill (2109).

(b) List of Utilization Technology of Coal Ash

	Application	Used Ash	Content and Utilization Factor Type
1	Cement admixtures	Fly ash	Made practicable, cement JIS standard is to be modified before long. (Large quantity)
	Ready mixed concrete	Fly ash	Made practicable (Large quantity)
2	Cement material	Raw powder Clinker ash	Substitute for clay Made practicable (Large quantity)
3	Concrete aggregate	Coarse powder Clinker ash	Made practicable for substituting for sand, (Large quantity)
	Cement secondary product	Fly ash Coarse powder	Board, panel, etc. (Middle)
	Roadbed material	Clinker ash Coarse powder	Under development (Middle)
4	Artificial light-weight aggregate	Coarse powder Raw powder	Succeeded in technology (Large quantity)
	Artificial heavy-weight aggregate	Coarse powder Raw powder	Commercialization will be studied from now on. (Large quantity)
5	Gathering-place for fish	Raw powder	Resin concrete system is under development. (Middle)
6	Special fertilizer	Raw powder	Made practicable as green ash (Small)
	Ordinary fertilizer	Raw powder	Potassium silicate fertilizer (Middle) (Mix with potash salt for heat treatment into water soluble potassium silicate fertilizer.)
7	Advanced utilization (Insulator, etc.)	Fly ash	Made practicable (Small)
8	Aluminum material		Under research in abroad
9	Non-cement hardening substance	Clinker ash Fly ash	Under research
10	Landfill, land preparation, agricultural land preparation		Made practicable (Large quantity)

5.2.2 Rehabilitation Plan for Termopalenque

In relation to the repair and improvement of the suspended #4 unit gas turbine generator, Westinghouse Corp. has submitted the following rehabilitation proposal.

(1) Equipment and devices delivered

1) A set of gas turbine packages
2) Electric appliances; synchronizing transmitter, converter for discharge temperature, start-up battery, instrumentations (diode for exciting unit, electromagnetic valve, etc.)
3) Special tools
   Various tools for installation, disassembly and start-up

(2) Content of works

1) Disassembly and removal of the existing gas turbine.
   Instruction to install a new gas turbine.
2) Instruction to assemble the gas turbine and generator.
3) Inspection for the generator and various auxiliary machines.
   Decision on the necessity of part exchange.

(3) Period to send instructor

One electrical engineer and one mechanical engineer are to be sent for 12 weeks, respectively.

(4) Exception

General tools and workers except for special tools required for the rehabilitation
(Mechanic, welder, plumber, instrumentation operator, controlling staff, electrician, general worker, etc.)
It is desirable that ESSA conducts the rehabilitation study under the witness and technical guidance of the supplier of the gas turbine,since the disassembly and inspection of the existing gas turbine or replacement and repair of parts belong to a black box of its supplier.

5.2.3 Rehabilitation Plan for Termobarranca

(1) Improvement of Cooling Water System

Fig. 5.2.10 shows improved cooling water system changed to closed cycle system.

- Head tank of cooling water (concrete type)	100 m^3 x 1 set
- Duplex filter (10")	1 set
- Cooler (Horizontal type)	
Primary cooling water temperature (inlet/outlet)	35°C/40°C
Secondary cooling water temperature (inlet/outlet)	30°C/25°C
- Water volume (Primary)	300 m^3/H

(2) Installation of an Automatic Condenser-Cleaning system

Remodel the water chamber of the existing condenser and, as shown in Fig. 5.2.11, mount an electric gate valve as the water chamber gate valve. An conceptional drawing of the condenser cleaning control is shown in Fig. 5.2.12.

The outline specifications are as follows:

- Cooling water capacity ; 11,300 m^3/h
- Size of cooling water piping ; 1,000ø
- Design pressure ; 3 kg/cm^2

(3) Change of instrumentation system

Convert the existing instrumentation system into electrical instrumentation.
(No data has been obtained in relation to the existing gauging site list, instrumentation list, control system drawing, etc.)

The main content is as follows:

- Replacement of transducer
- Remodeling of air piping
- Controlling power supply unit
- Installation of relay and control panel
- Cabling

(4) Installation of event recorder

The items measured by a newly installed event recorder are as follows:
(Data on the existing instrumentation, control, etc. have not been obtained in the same way as the above (3)).

1) Boiler concerned
   - Overall forced draft fan
   - Abnormally high or low of drum water level
   - Unstable combustion

2) Turbine concerned
   - Over-speed
   - Hot thrust bearing
   - Decreased oil pressure of bearing
   - Abnormal vibration

3) Generator concerned
   - Over-current
   - Abnormal vibration
   - Field loss

4) Transformer concerned
   - Over-current
   - Grounding accident
   - Abnormal frequency

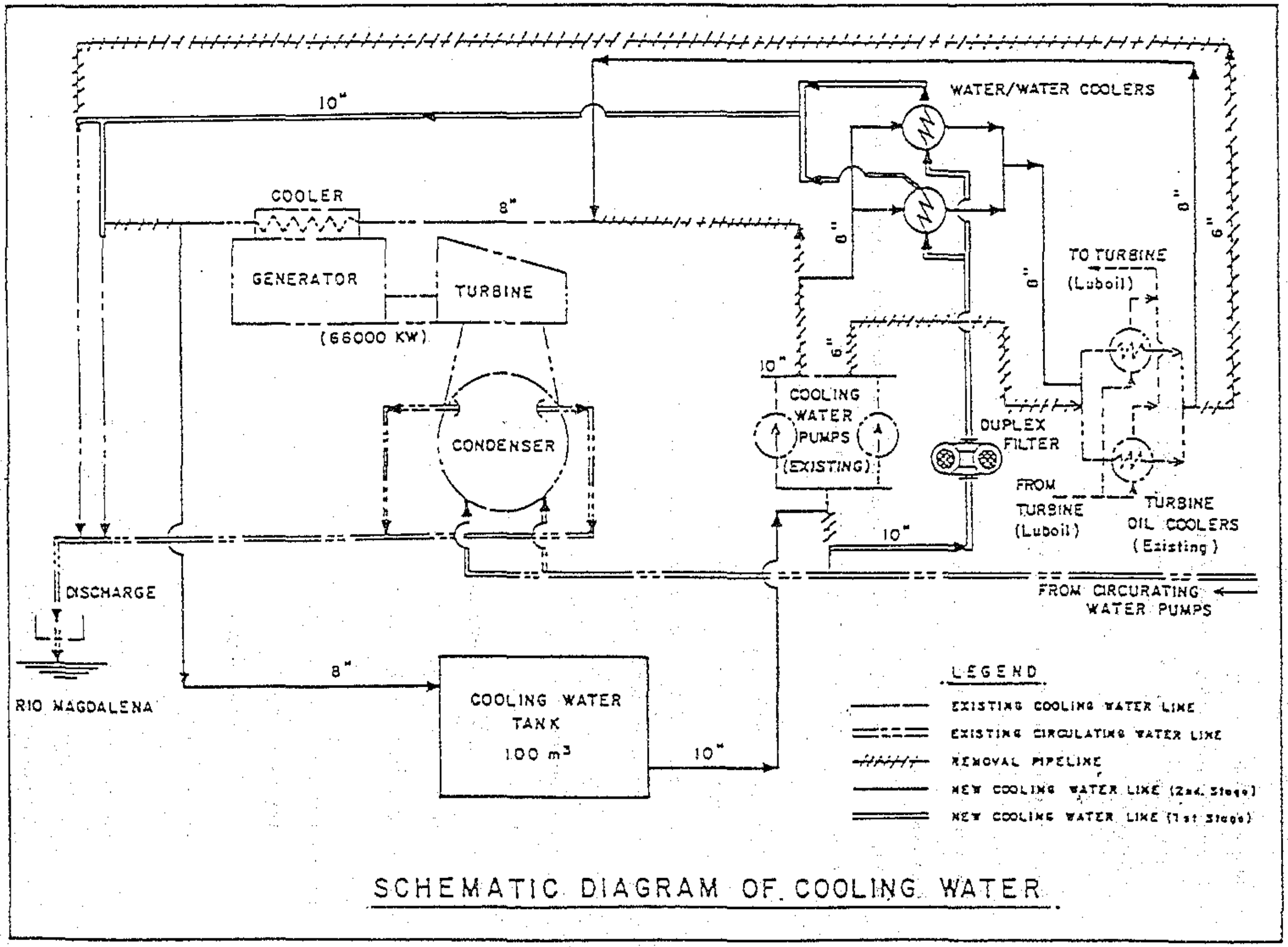
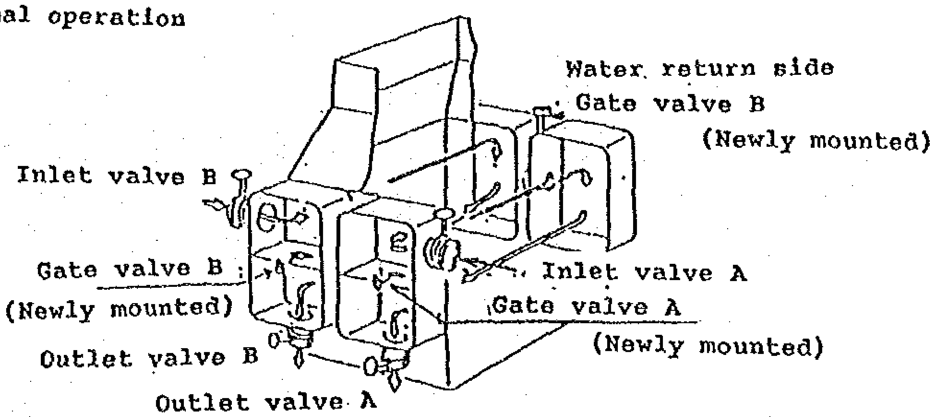
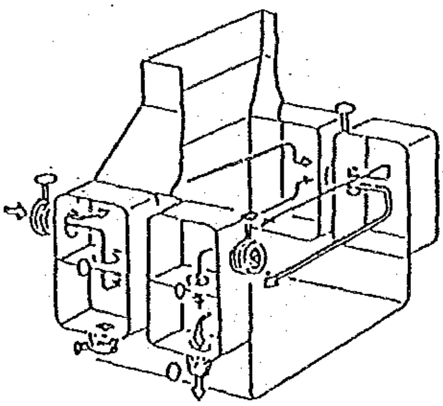


Fig. 5.2.10 Cooling Water System Drawing (Termobarranca #3 unit)

a) Normal operation



b) Back wash (I)



c) Back wash (II)

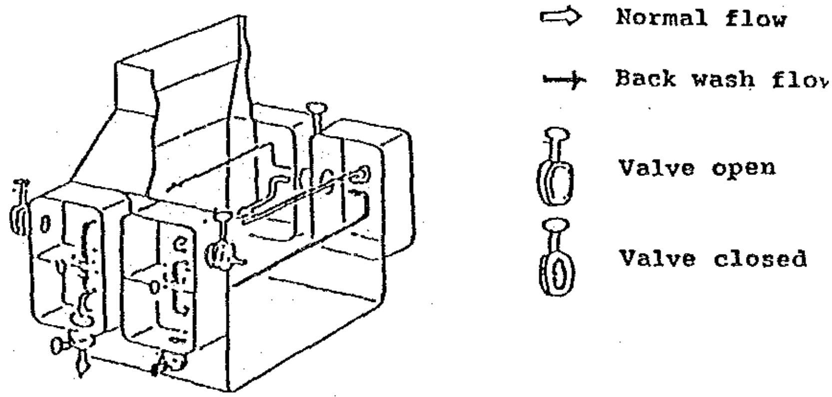
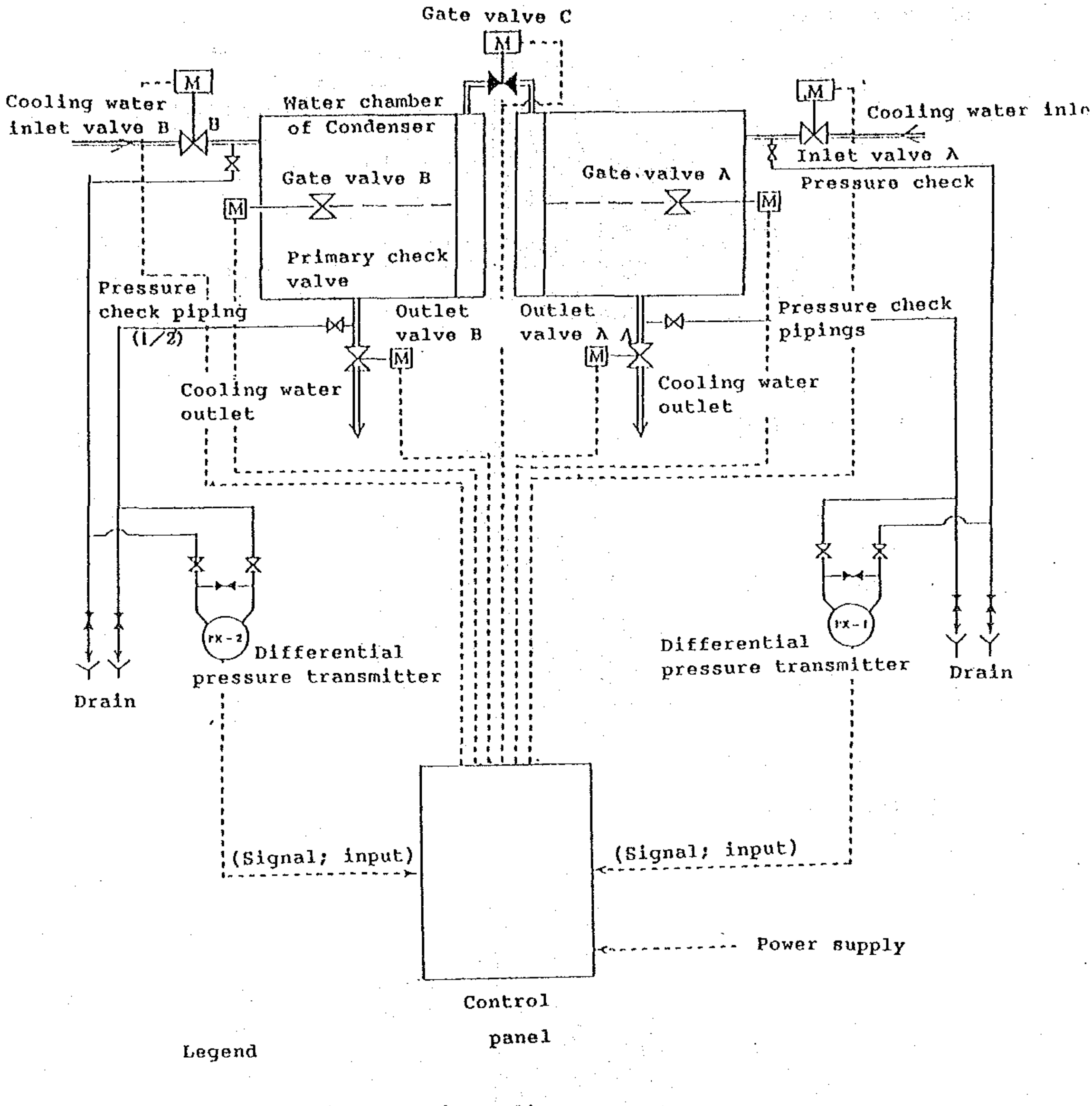


Fig. 5.2.11 Condenser Back-wash Valve Drawing (Contained Type)



Legend

⋈	;	Globe valve (manual)
[M] ⋈	;	Motor-operated valve
═══	;	Cooling water valve
———	;	Pressure check piping and drain pipe
------	;	Electric wire

Fig. 5.2.12 Conceptional Drawing of Condenser Wash Control System

5.3 Preliminary Rehabilitation Cost

The preliminary rehabilitation cost for each thermal power plant and the approximate rehabilitation cost per kW are as follows:

Power Plant	Approx. Rehabilitation Cost (10^6 US$)	Existing Installed Capacity (MW)	Rehabilitation Cost per Existing Installed Capacity (US$)
Termopaipa (#1, 2, & 3)	18.352	170	108
Termopalenque (#4)	4.6	15	307
Termobarranca (#3)	3.072	66	46.5
Total	26.023	251	103.7

Note: The river revetment works of Termobarranca power plant, which is a civil work, are excluded from this estimation.

The breakdown of approximate rehabilitation cost by each rehabilitation item is shown in Table 5.3.1.

Table 5.3.1 Approx. Rehabilitation Cost by Each Rehabilitation Item

Plant	Unit	Rehabilitation Items Requessted by ICEL	Breakdown of Approx. Rehabilitation Cost (Unit 10^3 US$)				
			Equip. (FOB)	Trans. & Insurance	Instl.	Civil Work	Sub-Total
Termo-paipa	#1	Replacement of air preheater for boiler	320	24	160	80	584
	#1	Installation of electrostatic precipitator	2,240	56	400	400	3,096
	#1 & 2	Change from pneumatic instrumentation system to electric one	1,600	16	160	0	1,776
	#2	Increase of turbine output	3,840	120	320	40	4,320
	#3	Change of ash disposal system	400	16	40	40	496
	#1, 2 & 3	Change of cooling water system	6,160	240	640	800	7,840
	#1, 2 & 3	Removal of water plant in cooling ponds	224	16	0	0	240
Termo-palenque	#4	Functional rehabilitation by replacement of gas turbine parts	4,000	160	400	40	4,600
Termo-barranca	#3	Improvement of cooling system	240	8	72	40	360
	#3	Installation of automatic condenser-cleaning device	320	8	160	0	488
	#3	Improvement of DC power supply system	240	8	72	0	320
	#3	Change from pneumatic instrumentation system to electric one	640	16	160	0	816
	#3	Installation of event recorder	800	40	240	8	1,088
		Total	21,024	728	2,824	1,448	26,024

5.4 Evaluation and Analysis

5.4.1 Evaluation and Analysis for Rehabilitation Item of Termopaipa

(1) Replacement of air pre-heater for #1 unit boiler

The following effects can be expected through the replacement of this equipment. However, taking into consideration that the service duration of the #1 unit (33 MW) is 29-year which is approx. twice as its useful life, it is doubtful whether this power plant deserves to be rehabilitated at its cost of US$584 thousand (US$17.7/kW per installed capacity).

(Rehabilitation effect)

- Output increase resulting from the improved operation efficiency (Approx. 1% to the installed capacity; 330 kW)
- Reducting effect of cost required for operation, maintenance and control personnel
- Reducting effect of fuel expenses

(2) Installation of electrostatic precipitator for #1 unit

For the environmental improvement, the law of Colombia obliges the installation of the electrostatic precipitator for the #1 unit. Thermal efficiency is reduced (approx. 1%) through the installation of the electrostatic precipitator. As previously described, the installation of this equipment entails the drastic modification in layout of this equipment and its surroundings including chimney. The total installation cost including modification amounts to approx. US$3.1 million (US$93.8/kW). Considering a shorter residual life, future power demand and environmental problems, it is recommended that the alternative plan for new construction of power plant rather than its rehabilitation or improvement to be examined.

(3) Change from pneumatic instrumentation system to electric one (#1 and #2 unit)

To improve the reliability of power plants, and solve the difficulty in procurement of spare parts, it is recommended to change to electric instrumentation system. The modification cost will be approx. US$18.4 per kW.

(4) Increase of turbine output for #2 unit (from 66 MW to 74 MW)

The rehabilitation entails the modification of related auxiliary equipment such as feed water heaters, etc. as well as turbine itself. The approximate modification cost for increasing the output of 8,000 kW is estimated to be approx. US$4.32 million and such cost per 1 kW to 8,000 kW is estimated to be US$540.
The generator with the installed capacity 74 MW has already been installed, so that this modification is likely to be realized.

(5) Change of ash disposal system for #3 unit

The maintenance cost of the existing ash disposal system is high, because the ash is conveyed under pressure through the pipeline. The change to a belt conveyor system has already been studied. Consequently, approx. US$ 496,000 has been appropriated as an approx. modification cost for changing to the belt conveyor system. The rehabilitation cost per installed capacity (74 MW) is US$6.7/kW.

(6) Securing of ash storage area

It is feared that the existing ash storage yards will be filled up in two years or so, and an urgent measure to meet this situation should be taken without delay. The counterplan to reduce the quantity handled of ash which results from the effective use of coal ash should be separately considered. But sufficient area for ash storage should be secured first.

The open type cooling water system for #1 through #3 unit are changed to the closed cycle type one using a cooling tower, and the method for changing the existing cooling ponds to a new ash storage yard is considered to be highly realized. Approximate equipment cost for changing to the closed cycle of cooling water system is US$7.84 million, while the amount invested per kW to the available capacity of 170 MW is estimated to be approx. US$46.4. However, the above approximate equipment cost contains no improvement cost for the Chicamocha River flowing down the existing cooling ponds.

(7) Removal of water plant on existing cooling ponds

Presently, water plants are removed only by the human power. Annual removal cost is approx. US$0.07/$m^2$, while the cost for purchasing an aquatic plant harvester is US$0.41/$m^2$.

As described in (6), if the cooling water system has been changed to the closed cycle system will the cooling tower, and the existing cooling ponds have been changed to the ash disposal yard, then this problem will naturally be solved.

It was found that arrangements have been made for the purchase of the aquatic plant harvester, when the secondary field reconnaissance of this power plant was conducted on February 26, 1988.
Therefore, this subject has already been solved.

5.4.2 Evaluation of #4 Unit for Termopalenque

(1) Rehabilitation cost per kW

The preliminary rehabilitation cost for replacing parts of #4 unit gas turbine suspended is US$4.60 million, which is equivalent to US$307 per kW. Generally, the installation cost of a new gas turbine generator having the output 15,000 kW is estimated to be approx. US$336/kW.

There is little difference between rehabilitation and installation costs. No rehabilitation effect may be expected, the rated output can be warranted for an extended period in the event of the rehabilitation.

(2) Generating cost

The generating cost is roughly calculated by the following formula.

$$I = \frac{C\gamma}{8{,}760L} + \frac{0.86f}{\alpha\eta} \quad \text{- - - - - - - - (Formula 5.4)}$$

where
- I = generating cost (US$/kWh)
- C = construction cost (US$/kW)
- f = fuel cost (US$/$10^3$ Kcal)
- α = thermal efficiency-reducing factor
- η = design thermal efficiency (%)
- γ = annual expense rate (%)
- L = capacity factor (%)

Table 5.4.1 Relation between Capacity Factor and Operation Efficiency

Capacity factor	100	90	80	70	60	50	40	30
Thermal efficiency-reducing factor	0.98	0.98	0.97	0.96	0.95	0.94	0.93	0.92

In case of this power plant, assuming each parameter is given as described below, the generating cost is roughly calculated by formula 5.4, as mentioned below:

- C = US$304/kW
- f = US$0.0016/$10^3$ Kcal (Col$101/$10^6$BTU = Col$0.4/ 10^3 Kcal)
- α = 0.92 (from Table 5.4.1)
- η = 36%
- γ = 17% (in the thermal power plant, it ranges from 15 to 19%, and its mean value of 17% is used)
- L = 30 (annual energy production during operation is 39,000 MWh. Therefore, the capacity factor is 30%)

$$I = \frac{304 \times 0.17}{8,760 \times 0.3} + \frac{0.86 \times 0.0016}{0.92 \times 0.36}$$

$$= \frac{51.68}{2,628} + \frac{0.0013}{0.004}$$

$$= 0.02 + 0.004$$

$$= US\$0.024$$

The generating cost is, therefore, US$0.024/kWh.

The rehabilitation should be studied with consideration given to the operation of the whole power system, because this power plant is directly connected to the national grid system.

5.4.3 Evaluation and Analysis of #3 Unit for Termobarranca

(1) Improvement of cooling water system

A plan for improving the cooling water system for turbine and generator to the closed cycle type one has been examined by the ESSA.

According to an improvement plan formulated by the ESSA, the preliminary improvement cost is estimated to be approx. US$360 thousand. The improvement cost per 1 kW to installed capacity of 66 MW is approx. US$5.44/kW and such cost per 1 kW to available output of 40 MW is approx. US$8.56/kW.

(2) Installation of automatic condenser cleaning device

With the installation of the automatic condenser-cleaning device is, the following effects are expected.

(Installation effect)

- Increase of output (approx. 330 to 660 kW) caused by improved operation efficiency
- Reducing effect of fuel cost per kWh
- Reducing effect of operation, maintenance and control cost

The approximate installation cost is US$488 thousand, and the amount invested is approx. US$7.36 per kW to the existing installed capacity.

(3) Improvement of DC power supply system

If improvement of this system causes the generator circuit breaker to work smoothly, the reduction in maintenance and rehabilitation cost can be expected. The improvement cost is approx. US$320 thousand and such cost per the existing installed capacity is approx. US$4.88/kW.

(4) Change from pneumatic type instrumentation system to electric type one

To improve the reliability of operation, maintenance and management, it is recommended to change to the electric type instrumentation system, which leads to the solution of the difficulty in procuring spare parts. The improvement cost is approx. US$816 thousand and such cost per kW to the existing installed capacity is approx. US$12.8/kW.

(5) Installation of event recorder

The installation of an event recorder permits the cause of accident to be easily analyzed, thus contributing to improved reliability of operation, maintenance and control. The installation cost is approx. US$1,088 thousand. The installation cost per 1 kW to the existing installed capacity (66 MW) and available output (40 MW) is US$16.48 and US$27.2, respectively.

5.5 Evaluation on Priority Order

5.5.1 Evaluation on Priority Order for Rehabilitation or Improvement

The rehabilitation or improvement items investigated or studied in each thermal power plant are excluded from the priority evaluation. Those are the following three items.

- Change of ash disposal system for #3 unit on Termopaipa Power Plant
- Problem concerning water plant removal in the existing cooling ponds on Termopaipa Power Plant
- Improvement of cooling water system for #3 unit for Termobarranca Power Plant

29 years have elapsed since #1 unit on Termopaipa Power Plant was installed in 1958, and both its equipment and facilities become deteriorated and have a fatal defects which does not conform to the present environmental control law. Thus, the following item, which require much cost for their rehabilitation and improvement, is excluded from the this evaluation on priority order.

- Replacement of boiler air-preheater for #1 unit on Termopaipa Power Plant

The revetment work of the Termobarranca River which has no connection with rehabilitation or improvement of generating facilities is also excluded.

The following evaluation items are set up for the remaining rehabilitation or improvement items. Table 5.5.1 shows the results of evaluation on the basis of 3-point evaluation method.

(1) Increase of output
(2) Simplicity of operation, maintenance and control
(3) Urgency of rehabilitation
(4) Degree of difficulty of rehabilitation

Table 5.5.1 Rating in Priority Order of Rehabilitation or Improvement

Thermal Power Plant	Unit No.	Installed Capacity (MW)	Installed Year	Rehabilitation or Improvement Items	Evaluation Items: Increase of Output	Simplicity of Operation, Maintenance & Control	Urgency of Rehabilitation	Degree of Difficulty in Rehabilitation	Total
Termopaipa	#2	66	1974	Change from penumatic instrumentation system to electric one	1	2	2	1	6
				Increase of turbine output (from 66 to 74 MW)	3	1	3	3	10
	#1, #2, #3			Securing of site for coal ash storage yard	2	2	3	1	8
Termopalenque	#4	15	1972	Recovery of function by replacement of gas turbine parts	3	1	3	1	8
Termobarranca	#3	74	1978	Installation of automatic condenser-cleaning system	2	3	2	2	9
				Improvement of direct current supply system	1	2	2	2	7
				Change from penumatic instrumentation system to electric one	1	2	2	1	6
				Installation of event recorder	1	2	2	1	6

The five items with high ratings are as follows:
- Increase of turbine output for #2 unit for Termopaipa Power Plant
- Securing of site for coal ash disposal yard for Termopaipa Power Plant
- Functional recovery by replacement of gas turbine parts for #4 unit on Termopalenque Power Plant
- Installation of automatic condenser-cleaning device for #3 unit on Termobarranca Power Plant
- Improvement of DC power supply system for #3 unit on Termobarranca Power Plant

5.5.2 Technical Evaluation on Countermeasures

Countermeasures for the remaining rehabilitation or improvement items may be divided into the following three classes from technical point of view.

Class- A : Items that were solved in the stage of Pre F/S

Class- B : All items can not be solved in the stage of the Pre F/S,but items that can be solved by ICEL group themselves according to the advice of the study team in the stage of the Pre F/S.

Class- C : Items requiring further detailed study and investigation in order to solve entirely

Table 5.5.2 shows the results evaluated on rehabilitation or improvement items according to the above three classes.

Table 5.5.2 Countermeasures for Rehabilitation or Improvement Items

Power Plant	Unit No.	Rehabilitation or Improvement Items	Technical Point of View A	B	C
Termopaipa	#1	Replacement of air-preheater for boiler	o		
Termopaipa	#1	Installation of electrostatic precipitator	o		
Termopaipa	#1, #2	Change from pneumatic instrumentation system to electric one		o	
Termopaipa	#2	Increase of turbine output		o	
Termopaipa	#3	Change of ash disposal system	o		
Termopaipa	#1, #2, #3	Change of cooling water system			o
Termopaipa	#1, #2, #3	Removal of water plant in the cooling ponds	o		
Termopalenque	#4	Functional recovery by replacement of gas turbine parts		o	
Termobarranca	#3	Improvement of cooling system	o		
Termobarranca	#3	Installation of condenser-cleaning system	o		
Termobarranca	#3	Improvement of direct current supply system	o		
Termobarranca	#3	Change from pneumatic instrumentation system to electric one		o	
Termobarranca	#3	Installation of event recorder	o		
Termobarranca	#3	River revetment work		o	

5.5.3 Evaluation on Priority Order

When priority under of candidate power plants for F/S is totally evaluated on the basis of the results of the above examination, their ratings are as follows:

1st place	Termopaipa Power Plant (except #1 unit)
2nd place	Termopalenque Power Plant
3rd place	Termobarranca Power Plant

Technical execution for formulating the rehabilitation plan in the stage of F/S is to be conducted by ICEL under guidance and advice from JICA study team members.

6. Rehabilitation Plan of Hydraulic Power Plants

6. REHABILITATION PLAN OF HYDRAULIC POWER PLANTS

6.1 Classification/Selection of Proposed Hydraulic Power Plants

The 62 hydraulic power plants proposed for rehabilitation plan, as described in Section 4.3.2, are classified into the following two groups; namely, five sites of reservoir type or pondage type power plants and 57 sites of run-of-river type power plants.

From the result of field investigation made in accordance with the questionnaire survey report provided by ICEL, such proposed hydraulic power plants are selected for the rehabilitation plan as follows:

Group - I Run-of-river Type Power Plants

(a) that are kept under the present condition,
(b) that are rehabilitated to the rated output,
(c) that are improved to more than the rated output,
(d) that have been ready for the expansion,
(e) that are expected to be expanded by changing the generating type.

Group - II Pondage or Reservoir Type Power Plants

(a) that are kept under the present condition,
(b) that have been ready for the expansion
(c) that are expected to increase the output by expanding.

6.1.1 Sites to be Exempted from Proposed Rehabilitation Plan

For the following reasons, there are 38 power plants in total as shown in Table 6.1.1, which are permitted to be exempted from the proposed rehabilitation plan.

R-1)	power plants that has already been under repair works	5
R-2)	power plants that are relinquished by public electric companies	1
R-3)	power plants in which ICEL group does not have water right	4
R-4)	power plants in which the river improvement works are included	1
R-5)	power plants for which the feasibility study has already been conducted	5
R-6)	power plants that are maintained in favorable operating conditions	11
R-7)	power plants whose priority order for the rehabilitation is evaluated to be low by the public electric companies	9
R-8)	power plants that are apparently judged to be improper for the rehabilitation as a result of the field reconnaissance	2
	Total	38

Table 6.1.1 Sites to be Kept in Existing State and Exemption Causes

Code No.	Department	Electric Power Company	Power Plants	Operation State	Exemption Factor							
					R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8
202	Antioquia	EADE	La Rebusca	O							x	-
203	Antioquia	EADE	La Calera	O							x	-
206	Antioquia	EADE	Sonson	O					x	x	-	-
207	Antioquia	EADE	Tamesis	O						x	-	-
208	Antioquia	E.P. de Urrao	Urrao	S	x	-	-	-	-	-	x	-
209	Antioquia	E.P. de Abejorral	Abejorral	O							x	-
214	Caldas	Chec	Guacaica	S	x	-	-	-	-	-	-	-
215	Caldas	E.P. de Salamina	Salamina	O							x	-
216	Caldas	E.P. de Anserma	Anserma	S		x	-	-	-	-	x	-
217	Risaralda	EPP	Belmonte	O						x	-	-
218	Risaralda	EPP	Dosquebradas	O						x	-	-
220	Quindio	E.P. de Armenia	El Bosque	S					x	-	-	-
224	Cauca	CEDELCA	Sajandi	O						x	x	-
225	Cauca	CEDELCA	El Palo	O						x	-	-
226	Cauca	CEDELCA	Mondomo	O						x	x	-
229	Cauca	CEDELCA	Asnazu	O							x	-
230	Cauca	CEDELCA	Inza	S	x	-	-	-	-	-	-	-
231	Cauca	CEDELCA	Toribio	O							x	-
234	Cundinamarca	ECSA	La Salada	S								x
235	Cundinamarca	ECSA	Rio Negro	O				x	-	-	-	-
236	Cundinamarca	E.P. de Choachi	Choachi	O								x
239	Huila	E. Huila	La Pita	O						x	-	-
240	Huila	E. Huila	Fortalecillas	S			x	-	-	-	-	-
243	Meta	E.P. de El Calvario	El Calvario	O						x	-	-
244	Meta	E.P. de San Juanito	San Juanito	O						x	-	-
245	Nariño	CEDENAR	Rio Mayo-II	O						x	-	-
246	Nariño	CEDENAR	Rio Bobo	S	x	-	-	-	-	-	-	-
247	Nariño	CEDENAR	Rio Sapuyes	O							x	-
249	Putumayo	E.P. de Mocoa	Mulato	S			x	-	-	-	-	-
250	Santander	ESSA	Palmas	O					x	-	-	-
252	Santander	ESSA	Cascada	O					x	-	-	-
253	Santander	ESSA	Comoda	S					x	-	-	-
254	Santander	ESSA	Servita	O							x	-
255	Santander	ESSA	Calichal	O							x	-
257	Tolima	E. Tolima	Rio Recio	O			x	-	-	-	x	-
259	Tolima	E. Tolima	Pastales	S	x	-	-	-	-	-	-	-
260	Tolima	E. Tolima	Rio Prado	O						x	-	-
262	Tolima	E. Tolima	Ventanas	O			x	-	-	-	x	-

R-1 through R-8 means the cause described in the previous page.

Mark O in the operation state column means 'in operation' while the mark S means 'suspended'.

(1) Power plants to be kept in a very good operation state

The following two points are considered for descrimination of the operating situation of R-6 in Table 6.1.1.

1. The headrace structures are rigid and maintenance and control situation is very good.

2. The maintenance and control situation in the power plants is good, and the available output of the power plants shall be more than 75% to the rated output.

The operation state in R-6 described in Table 6.1.1 is shown in Table 6.1.2.

Table 6.1.2 Proposed Power Plants to be kept in a Good Operation State

Code No.	Power Plant	Department	Rated Output, P_1 (kW)	Available Output, Pe (kW)	Pe/Pl (%)
206	Sonson	Antioquia	3,600	3,600	100
207	Tamesis	Antioquia	1,508	1,160	77
217	Belmonte	Risaralda	3,760	3,300	88
218	Dos Quebradas	Risaralda	8,500	8,200	96
224	Sajandi	Cauca	2,480	1,640	66
225	El Palo	Cauca	1,440	1,280	89
226	Mondomo	Cauca	600	470	78
239	La Pita	Huila	1,420	1,060	75
243	El Calvario	Meta	20	16	80
244	San Juanito	Meta	20	20	100
245	Rio Mayo-II	Narino	21,000	20,000	95
260	Rio Prado	Tolima	51,000	51,000	100

(2) Power plants where F/S has been conducted

For five power plants listed in R-8), the following study reports have been submitted.

Code No.	Power Plant	Department	Title	Submitted by	Submitted Date
206	Sonson	Antioquia	Plan Global de Electrificacion Rural	Mejia Villegas S.A	March 1987
220	El Bosque	Quindio	Estudio para la Rehabilitacion de la Central Hidroelectrica	Univercidad Nacional de Colombia Seccional Manisalez	February 1988
250	Palmas	Santander	Unconfirmed	Colconsult LTDA. (Bogota)	1981
252	Cascada	Santander	Optimizacion Centrales La Cascada y La Comoda	Consultores Regionales Asociados LTDA.	July 1980
253	Comoda				

6.1.2 Power Plants Where There Are No Hydrological Gauging Stations Nearly

As described in Section 4.3.2, there are no hydrological-gauging stations near the power plants listed in Table 4.3.7. For this reason, no hydrological gauging data required for the rehabilitation plan have been obtained.

However, for Abejorral Power Plant in Antioquia Department, there is a private power plant operated by a private cement company (Cemento el Cairo S.A). If the quantity of water intake for the relevant power plant is found, the data may be useful.

6.1.3 Power Plants that Have been Ready for Expansion

Both the Sonson Power Plant in Antioquia department (EADE) and the Inza Power Plant in Cauca department (CEDELCA) have been designed considering the future expansion.

(1) Sonson (Rated output: 3,600 kW, planned output for expansion 3,600 kW plus 4,000 kW)

This power plant is of the pondage type and, the headrace structures ranging from intake to surge tank have been constructed to provide for the future expansion of one unit. Such an expansion can only have to be made by additionally constructing the penstock and generating facilities. For this plant, taking into consideration of the third unit for the expansion, another penstock branch pipe has been installed on the surge tank. However, this pipe is located outside of the valve room, and the power generating building also has no available space. One of the reasons why no expansion has been actualized is water shortage during droughts.

(2) Inza (rated output: 360 kW, planned output for expansion: 360 kW)

This power plant is of the run-of-river type, the headrace structures ranging from intake to surge tank have been constructed considering the future expansion. Since the space for powerhouse building has been secured, the expansion is possible if the penstock and the generating facilities are additionally installed and the outlet is provided. The river has an abundant flow. A sharply increasing output other than 360 kW may be expected if the expansion is made.

6.1.4 Power Plants to be Rehabilitated upto the Rated Output

The purpose of the rehabilitation is to analyze the causes why the power plant is suspended or the available output is much lower than a rated output and to recover the output to the rated level.

24 power plants as shown in Table 6.1.3 are selected as proposed power plants to be rehabilitated upto the rated output through the classification process as mentioned above.

Table 6.1.3 Power Plants to be Rehabilitated upto the Rated Output

Code No.	Power Plant	Department	Operation State: Rated Output P_1 (kW)	Operation State: Available Output Pe (kW)	Pe/P_1 (%)	River
201	Caracoli	Antioquia	3,200	2,300	72	Nus
204	Rio Abajo	Antioquia	1,000	600	60	Negro
205	Piedras	Antioquia	458	250	53	Piedras
210	P. Guillermo	Boyaca	1,280	0	0	Suarez
211	San Cancio	Caldas	2,320	1,750	75	Chinchina
212	Intermedia	Caldas	1,120	900	80	Chinchina
213	Municipal	Caldas	2,112	1,400	66	Chinchina
219	Santa Rosa	Risaralda	450	139	31	San Eugenio
221	Bayona	Quindio	1,008	159	16	Quindio
222	Campestre	Quindio	1,120	62	6	Quindio
223	La Union	Quindio	1,000	0	0	Quindio
227	Silvia	Cauca	604	100	17	Piendamo
228	Ovejas	Cauca	900	650	72	Ovejas
232	Florida-I	Cauca	2,300	0	0	Cauca
233	La Vuelta	Choco	2,000	500	25	Andagueda
237	Apulo	Cundinamarca	3,000	0	0	Bogota
238	La Viciosa	Huila	225	0	0	Q. Viciosa
241	Rio Iquira-I	Huila	4,320	2,230	52	Iquira
242	Rio Iquira-II	Huila	2,400	700	29	Iquira
248	Julio Bravo	Narino	1,500	0	0	Pasto
251	Zaragoza	Santander	1,560	800	51	Surata
256	Guali	Tolima	1,048	0	0	Guali
258	Mirolindo	Tolima	3,600	1,000	28	Combeima
261	Lagunilla	Tolima	452	0	0	Lagunilla

Among the candidate power plants for rehabilitation as listed in Table 6.1.3, those with high output recovery factor (= recovery output/rated output) are given as follows:

Table 6.1.4 Power Plants with a High Output Recovery Factor upto the Rated Output

Code No.	Power Plant	Department	Recovery Output (kW)	Recovery Factor (%)
210	P. Guillermo	Boyaca	1,000	86
219	Santa Rosa	Risaralda	371	82
222	Campestre	Quindio	938	84
223	La Union	Quindio	840	84
232	Florida-I	Cauca	2,400	104
233	La Vuelta	Choco	1,500	75
237	Apulo	Cundinamarca	2,700	90
238	La Visiosa	Huila	170	76
248	Julio Bravo	Nariño	1,800	120
256	Guali	Tolima	1,300	124
261	Lagunilla	Tolima	470	104

6.1.5 Power Plants that Improvement upto More than Rated Output is Expected

When the existing facilities are rehabilitated, the output is expected to increase upto more than rated output if the following conditions are satisfied.

(1) Power plants where the present design discharge is estimated to increase according to hydrological regime of the river.

(2) Power plants where the length of the headrace is short and the design discharge and effective head could be increased at a small cost of modification.

(3) Power plants where the installed capacity is much smaller in comparison with a theoretical output.

Among the sites to be rehabilitated to the rated output as listed in Table 6.1.3, the proposed sites to be expected for output increase more than a rated output are as follows:

Table 6.1.5 Proposed Power Plants where Improvement upto More than the Rated Output Is Expected

Code No.	Power Plant	Department	Rated Output (kW)	Increased Output (kW)	Increase Rate (%)
212	Intermedia	Caldas	1,120	2,500	2.2
213	Municipal	Caldas	2,112	3,500	1.7
227	Silvia	Cauca	604	1,700	2.8
233	La Vuelta	Choco	2,000	7,500	3.8
248	Julio Bravo	Nariño	1,500	2,300	1.5
251	Zaragoza	Santander	1,560	3,500	2.2
256	Guali	Tolima	1,048	4,300	4.1
261	Lagunilla	Tolima	452	4,300	9.5

6.1.6 Power Plants where Expansion is Expected by Changing the Generating Method

Among the candidate power plants for rehabilitation, a drastic increase of the output is expected as shown Table 6.1.6, if the hydrological data for the power plants excluded from the rehabilitation plan are kept in readiness and head condition is effectively utilized.

It is necessary to keep in readiness and analyze fundamental data such as hydrological flow, topography, geology, etc. and to validate the feasibility. According to the results of the field reconnaissance, the approximate output was estimated as follows:

Table 6.1.6 Power Plants whose Increase of Output is Expected

Code No.	Power Plant	Department	Check Point	Present Installed Capacity (kW)	Estimated Output (kW)
207	Tamesis	Antioquia	Effective utilization of head condition and increase of available discharge	1,508	6,000
230	Inza	Cauca	Increase of available discharge	360	16,000
246	Rio Bobo	Narino	Use of existing reservoir in the upstream and effective utilization of head condition	4,368	15,000

6.1.7 Classification Proposed Power Plants by Group

According to the classification method as mentioned above, proposed 62 power plants are classified as follows. However, the total number is more than the realistic number of proposed power plants, because of overlapped counting.

Group I : Run-of-River Type Power Plants 57

- (a) that are kept under the present condition, 33
- (b) that are rehabilitated to the rated output, 22
- (c) that are improved to more than the rated output, 8
- (d) that have been ready for the expansion, 1
- (e) that are expected to be expanded by changing the generating type. 3

Group - II: Pondage or Reservoir Type Power Plants 5

- (a) that are kept under the present condition, 5
- (b) that have been ready for the expansion 1
- (c) that are expected to increase the output by expanding. 0