(a) Total cost is divided into equalized three portions, interest rates of which are 3%, 8.5% and 8.1% per anum respectively.

(b) Periods of repayment are 30 years, 20 years and 25 years including grace periods.

(c) Repayment will be made in annual equal installments.

(4) Interest during construction of foreign loan

As shown on Table 9-6, the interest during construction including related transmission lines as shown on 9.2.3. is estimated at Pesos 1,980,644 x 10^3.

(5) Principal repayment and interest payment after start of commercial operation

The principal repayment and interest payment after start of commercial operation are shown on Table 9-7, including related transmission equipment.

9.2.3. Transmission Lines Associated with Power Plants

(1) Technical data of associated transmission lines

(a) Sequence of development

Section	Route	Completion
CFTH III - Santiago 230 kV	2 circuit 1 route with bundle 2 conductors	End of 1992
Chico IV - Solano 230 kV	2 circuit 1 route with bundle 2 conductors	End of 1993
Diduyon - Solano 230 kV	2 circuit 1 route with single conductor	End of 1994

(b) Construction cost of 230 kV overhead line with bundle 2 conductors — US$ 178,944 (Pesos 1,342,080)

or single conductor per km per route — US$ 117,953 (Pesos 884,650)

(c) Annual OM cost — 2.5% of the investment cost

(2) Disbursement schedule of capital cost

The disbursement schedule of the capital cost with cost escalation is included Table 9-5. The foreign currency requirement is estimated at US$ 14,159 x 10^3 (₱ 106,192 x 10^3) and the local currency Pesos 200,494 x 10^3, which amount to Pesos 306,686 x 10^3. The costs will be disbursed from 1990 to 1994.

(3) Condition of loan of foreign exchange cost

The following assumptions were used for the financial analysis.

(a) Rate of interest per annum - 3.0%
(b) Period of repayment is 30 years including a grace period of 10 years.
(c) Repayment will be made in annual equal installments.

(4) Interest during construction of foreign loan

As shown on Table 9-6 the interest during construction is estimated at Pesos 35,786 x 10^3.

(5) Principal repayment and interest payment after start of commercial operation

The principal repayment and interest payment after start of commercial operation are shown on Table 9-7.

9.2.4. Power Rate

The local currency cost will be financed by the NAPOCOR internal reserves and an equity contribution from the government. Under this condition of local cost finance, the power rate that will be able to pay for the financial cost required for the foreign loan and the OM cost, keeping a financial rate of return of 8%, is estimated to be 108.14 centavos per kWh. (See Table 9-8).

9.2.5. Cash Flow and Debt Service Ratio

The projected cash flow statement of the Project with the cost escalation is presented on Table 9-9. This table indicates that the debt service ratio is 2.56 in the initial year of the commercial operation and it reaches more than 5 after the year of 1995, thereafter increasing sharply with a decrease in the yearly payments. Accordingly, if the power rate of 108 centavos per kWH about 3 times the average rate 35.32 ¢/kWH as of 1980 is secured, the income derived from this power rate will generate funds necessary for payment of principal and financial costs.

9.2.6. Financial Analysis at a Higher Rate of Interest on Foreign Cost of the Project

An alternative financial analysis was made on the assumption that only the financial condition of the foreign cost of the Project is changed as follows:

Table 9-1 Economic Internal Rate of Return

(₱ 10^3)

No.	Year	COST						BENEFIT					
		Investment		O & M		Others (Fuel)	Total	Investment		O & M		Others	Total
		P/S	T/L & S/S	P/S	T/L & S/S			P/S	T/L & S/S	P/S	T/L & S/S		
1	1981	228,740					228,740						0
2	1982	482,450					482,450						0
3	1983	582,650					582,650						0
4	1984	578,930	63,330				642,260	574,674	10,706				585,380
5	1985	717,360	597,786				1,315,146	915,147	94,244				1,009,391
6	1986	674,990	936,419				1,611,409	1,405,456	130,184				1,535,640
7	1987	337,210	810,874				1,148,084	653,048	158,688				811,736
8	1988	87,840	-	17,616	63,614		169,070	274,380	-	40,885	10,478	138,360	464,103
9	1989	274,380	138,860	35,232	63,614		512,086	436,940	30,325	81,771	10,478	276,720	836,234
10	1990	796,940	27,930	35,232	63,614		923,716	1,084,438	39,337	81,771	10,478	276,720	1,492,744
11	1991	1,787,670	90,813	35,232	63,614		1,977,329	1,366,145	91,975	81,771	10,478	276,720	1,827,089
12	1992	1,989,350	137,238	35,232	63,614		2,225,434	1,641,684	142,430	81,771	10,478	276,720	2,153,083
13	1993	1,125,850	136,871	67,767	65,514	477,360	1,873,362	1,438,313	115,126	114,306	13,133	754,080	2,434,958
14	1994	373,000	43,650	88,906	72,642	477,360	1,055,558	450,031	53,780	163,326	18,164	947,040	1,632,341
15	1995	0	17,255	109,164	75,180	477,360	678,959	0	11,649	210,285	22,182	1,175,040	1,419,156
16	1996		6,182	109,164	75,180	477,360	667,886		8,826	210,285	22,182	1,175,040	1,416,333
17	1997		0	109,164	75,180	477,360	661,704		0	210,285	22,182	1,175,040	1,407,507
⋮	⋮			⋮	⋮	⋮	⋮			⋮	⋮	⋮	⋮
29	2009			109,164	75,180	477,360	661,704			210,285	22,182	1,175,040	1,407,507
30	2010			109,164	75,180	477,360	661,704			210,285	22,182	1,175,040	1,407,507
Total		10,037,360	3,007,208	2,061,841	1,659,106	8,592,480	25,357,995	10,240,256	887,270	4,010,161	438,599	21,747,000	37,323,286

Computed economic internal rate of return (EIRR) = 13.46 %

C: Cost = 6,845,173 x 10^3

B: Benefit = 6,847,716 x 10^3

B/C = 1.00037

(a) Interest = 8.5% per annum

(b) Repayment = 20 years including grace period

(c) Grace period = construction periods

The result of alternative financial analysis is summarized as follows:

(₱ 10^3)

	Item	Original Analysis	Alternative Analysis	Ratio
1.	Interest during construction	2.111,500	2,417,013	1.14
2.	Paid interest	8,366,524	5,106,341	1.09
3.	Power rate at financial rate of return 8%	108.14 centavos	112.10	1.04
4.	Debt service ratio at initial year	2.56	2.58	1

Table 9-3 Interest during Construction of the Project

Interest	:	3% per anum
Repayment	:	30 years including grace period
Grace Period	:	10 years
Principal Repayment	:	annual equal installment

(₱ 10^3)

No.	Year	Draw-down	Outstanding Loan	Interest during Construction
1	1984	84,866	84,866	2,546
2	1985	571,430	656,296	19,689
3	1986	851,209	1,507,505	45,225
4	1987	605,718	2,113,223	63,396
5	1988	-	(2,113,223)	-
6	1989	232,155	(2,345,378)	-
Total		2,345,378		130,856

Note : Commencing year of the Project is expected to be in 1988.

Table 9-4 Principal Repayment and Interest Payment of the Project

(₱ 10^3)

No.	Year	Year End Principal	Principal Repayment	Interest Payment
1	1988	2,113,223		63,397
2	1989	2,345,378		70,361
3	1990	"		"
4	1991	"		"
5	1992	"		"
6	1993	"		"
7	1994	2,228,109	117,269	"
8	1995	2,110,840	"	66,843
9	1996	1,993,571	"	63,325
10	1997	1,876,302	"	59,807
11	1998	1,759,033	"	56,289
12	1999	1,641,764	"	52,771
13	2000	1,524,495	"	49,253
14	2001	1,407,226	"	45,735
15	2002	1,289,957	"	42,217
16	2003	1,172,688	"	38,699
17	2004	1,055,419	"	35,181
18	2005	938,150	"	31,663
19	2006	820,881	"	28,145
20	2007	703,612	"	24,626
21	2008	586,343	"	21,108
22	2009	479,074	"	17,590
23	2010	351,805	"	14,072
24	2011	234,536	"	10,554
25	2012	117,268	117,268	7,036
26	2014	0	"	3,518
Total			2,345,378	1,153,995

Table 9-5 Disbursement Schedule of the Capital Costs for Power Plants Including Rebated Transmission Lines

(₱ 10^3)

No.	Year	Foreign Cost	Local Cost	Total
1	1981	82,652	184,730	267,382
2	1982	217,245	434,900	652,145
3	1983	257,164	641,344	916,508
4	1984	406,159	595,547	1,001,706
5	1985	534,075	892,396	1,426,471
6	1986	462,652	1,148,846	1,611,498
7	1987	397,860	372,134	769,994
8	1988	59,282	237,958	297,240
9	1989	401,692	367,908	769,600
10	1990	1,055,455	1,980,846	3,036,301
11	1991	2,307,526	5,915,335	8,222,861
12	1992	2,440,013	9,179,441	11,619,454
13	1993	1,324,679	7,035,791	8,360,470
14	1994	485,390	2,765,919	3,251,309
Total		10,449,844	31,753,095	42,202,939

Table 9-6 Interest during Construction of the Power Plants Projects Including Related Transmission Lines
(Each projects are divided into equalized 3 portions)

Interest 3, 8.5% and 8.1% per anum

Repayment: 30, 20 and 25 years

Grace Period: 10 years, construction periods for the letter two

(₱ 10^3)

No.	Year	Draw-down	Outstanding Loan	Interest during Construction
1	1981	82,652	82,652	5,400
2	1982	217,245	299,897	19,593
3	1983	275,164	575,061	37,571
4	1984	406,159	981,220	64,104
5	1985	534,075	1,515,295	98,999
6	1986	462,652	1,977,947	129,224
7	1987	397,860	2,375,807	155,217
8	1988	59,282	2,435,089	159,092
9	1989	401,692	2,836,781	26,244
10	1990	1,055,455	3,892,236	94,329
11	1991	2,307,526	6,199,762	246,570
12	1992	2,440,013	8,639,775	410,155
13	1993	1,324,679	9,964,454	319,544
14	1994	485,390		214,602
Total		10,449,844		1,980,644

Note : This table is not usable for direct calculation of IDC, since IDC was calculated with different interest rates separately.

Table 9-7 Principal Repayment and Interest Payment for Power Plants Including Related Transmission Lines

(₱ 10^3)

No.	Year	Principal Repayment	Interest Payment
1	1989	115,389	159,092
2	1990	115,389	149,475
3	1991	155,974	139,858
4	1992	155,973	129,023
5	1993	257,659	302,050
6	1994	324,573	420,978
7	1995	449,534	612,031
8	1996	449,534	577,262
9	1997	449,533	541,978
10	1998	449,533	506,682
11	1999	501,014	471,418
12	2000	577,026	434,592
13	2001	550,093	395,489
14	2002	550,093	360,912
15	2003	550,093	326,337
16	2004	550,092	291,759
17	2005	550,091	257,180
18	2006	502,344	222,607
19	2007	502,344	191,896
20	2008	502,344	161,184
21	2009	444,631	130,476
22	2010	373,224	104,672
23	2011	294,894	84,941
24	2012	294,893	69,632
25	2013	294,892	54,326
26	2014	250,921	39,016
27	2015	197,365	27,274
28	2016	168,198	19,863
29	2017	168,198	14,815
30	2018	168,198	9,769
31	2019	116,718	4,723
32	2020	40,708	1,219

Table 9-8 Financial Rate of Return

(₱ 10^3) (1/2)

No.	Year	COST						REVENUE		
		IDC & Comm. fee	Principal Repayment	Interest Payment	Local Cost	Q & M	Total	Rate c/kWh	Energy (GWh)	Revenue
1	1981	5,400			184,730		190,130		0	0
2	1982	19,593			434,900		454,493		0	0
3	1983	37,571			641,344		678,915		0	0
4	1984	66,650			600,448		667,098		0	0
5	1985	118,688			1,424,873		1,543,561		0	0
6	1986	174,449			2,350,445		2,524,894		0	0
7	1987	218,613			2,004,599		2,223,212		0	0
8	1988	159,092		63,397	237,958	81,230	541,677	108.14	576	622,886
9	1989	26,244	115,389	229,453	367,908	98,846	837,840	108.14	1,153	1,246,854
10	1990	94,329	115,389	219,836	1,980,846	98,846	2,509,246	108.14	1,153	1,246,854
11	1991	246,570	155,974	210,219	5,915,335	98,846	6,626,944	108.14	1,153	1,246,854
12	1992	410,155	155,973	199,384	9,179,441	98,846	10,043,799	108.14	1,153	1,246,854
13	1993	319,544	257,659	372,411	7,035,791	610,641	8,596,046	108.14	3,142	3,397,759
14	1994	214,602	441,842	491,339	2,765,919	638,908	4,552,610	108.14	3,946	4,267,204
15	1995		566,803	678,874		661,704	1,907,381	108.14	4,986	5,294,534
16	1996		566,803	640,587		661,704	1,869,094	108.14	4,896	5,294,534
17	1997		566,802	601,785		661,704	1,830,291	108.14	4,896	5,294,534
18	1998		566,802	562,971		661,704	1,791,477	108.14	4,896	5,294,534
19	1999		618,283	524,189		661,704	1,804,176	108.14	4,896	5,294,534
20	2000		694,295	483,845		661,704	1,839,844	108.14	4,896	5,294,534
21	2001		667,362	441,224		661,704	1,770,290	108.14	4,896	5,294,534
22	2002		667,362	403,129		661,704	1,732,195	108.14	4,896	5,294,534
23	2003		667,362	365,036		661,704	1,694,102	108.14	4,896	5,294,534
24	2004		667,361	326,940		661,704	1,656,005	108.14	4,896	5,294,534
25	2005		667,360	288,843		661,704	1,617,907	108.14	4,896	5,294,534

(₱ 10^3) (2/2)

No.	Year	COST						REVENUE		
		IDC & Comm.fee	Principal Repayment	Interest Payment	Local Cost	O & M	Total	Rate c/kWh	Energy (GWh)	Revenue
26	2006		619,613	250,752		661,704	1,532,069	108.14	4,896	5,294,534
27	2007		619,613	216,522		661,704	1,497,839	108.14	4,896	5,294,534
28	2008		619,613	182,292		661,704	1,463,609	108.14	4,896	5,294,534
29	2009		561,900	148,066		661,704	1,371,670	108.14	4,896	5,294,534
30	2010		490,493	118,744		661,704	1,270,941	108.14	4,896	5,294,534
31	2011		412,163	95,495		661,704	1,169,362	108.14	4,896	5,294,534
32	2012		412,161	76,668		661,704	1,150,533	108.14	4,896	5,294,534
33	2013		412,160	57,844		661,704	1,131,708	108.14	4,896	5,294,534
34	2014		250,921	39,016		661,704	951,641	108.14	4,896	5,294,534
35	2015		197,365	27,274		661,704	886,343	108.14	4,896	5,294,534
36	2016		168,198	19,863		661,704	849,765	108.14	4,896	5,294,534
37	2017		168,198	14,815		661,704	844,717	108.14	4,896	5,294,534
38	2018		168,198	9,769		661,704	839,671	108.14	4,896	5,294,534
39	2019		116,718	4,723		661,704	783,145	108.14	4,896	5,294,534
40	2020		40,708	1,219		661,704	703,631	108.14	4,896	5,294,534
Total		2,111,500	13,416,843	8,366,524	35,124,537	18,930,467	77,949,871			150,933,149

Discount rate : 8%   Cost = ₱ 24,756,584   Revenue/Cost = 0.99997

Revenue = ₱ 24,755,739

Table 9-9 Projected Cash Flow Statement (1981 - 2020)

(Unit : ₱ x 10^3) (1/4)

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
I. Source of Funds										
A. Internal Cash Generation										
A-1 Income								622,886	1,246,854	1,246,854
A-2 Depreciation								253,868	253,868	253,868
B. Foreign Borrowing	82,652	217,245	275,164	491,025	1,105,505	1,313,861	1,003,578	59,282	667,467	1,055,455
C. Equity Contribution	190,130	454,493	678,915	667,098	1,543,561	2,524,894	2,223,212	397,050	394,152	2,075,175
TOTAL SOURCE OF FUNDS	272,782	671,738	954,079	1,158,123	2,649,066	3,838,755	3,226,790	1,333,086	2,562,341	4,631,352
II. Application of Funds										
A. Addition to Plant/Transmission Line	267,382	652,145	916,508	1,091,473	2,530,378	3,664,306	3,008,177	297,240	1,035,375	3,036,301
B. Project										
B-1 Interest during Construction				2,546	19,689	45,225	63,396			
B-2 Operating Interest								63,397	71,370	71,370
B-3 Principal Repayment										
C. Power Plants & Associated Transmission										
C-1 Interest during Construction	5,400	19,593	37,571	64,104	98,999	129,224	155,217	159,092	26,244	94,329
C-2 Operating Interest									159,092	149,475
C-3 Principal Repayment									115,389	115,389
TOTAL APPLICATION OF FUNDS	272,782	671,738	954,079	1,158,123	2,649,066	3,838,755	3,226,790	519,729	1,407,470	3,466,864
III. Cash Excess (Deficit)	0	0	0	0	0	0	0	813,357	1,154,871	1,164,488
Debt Service Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.56	1.82	1.34

(Unit : ₱ x 10^3) (2/4)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
I. Source of Funds										
A. Internal Cash Generation										
A-1 Income	1,246,854	1,246,854	3,397,759	4,267,204	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534
A-2 Depreciation	253,868	253,868	445,269	648,166	1,036,629	1,035,629	1,035,629	1,035,629	1,035,629	1,035,629
B. Foreign Borrowing	2,307,526	2,440,013	1,324,679	485,390						
C. Equity Contribution	6,161,905	9,589,596	7,355,335	2,980,521						
TOTAL SOURCE OF FUNDS	9,970,153	13,530,331	12,523,042	8,381,281	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163
II. Application of Funds										
A. Addition to Plant/Transmission Line	8,222,861	11,619,454	8,360,470	3,251,309						
B. Project										
B-1 Interest during Construction										
B-2 Operating Interest	71,370	71,370	71,370	71,370	67,801	64,233	60,664	57,096	53,527	49,959
B-3 Principal Repayment				118,950	118,950	118,950	118,950	118,950	118,950	118,950
C. Power Plants & Associated Transmission										
C-1 Interest during Construction	246,570	410,155	319,544	214,602						
C-2 Operating Interest	139,858	129,023	302,050	420,978	612,031	577,262	541,978	506,682	471,418	434,592
C-3 Principal Repayment	155,974	155,973	257,659	324,573	449,534	449,534	449,533	449,533	501,014	577,026
TOTAL APPLICATION OF FUNDS	8,836,633	12,385,975	9,311,093	4,401,782	1,248,316	1,209,979	1,171,125	1,132,261	1,144,909	1,180,527
III. Cash Excess (Deficit)	1,133,520	1,144,356	3,211,949	3,979,499	5,081,847	5,120,184	5,159,038	5,197,902	5,185,254	5,149,636
Debt Service Ratio	1.13	1.09	1.34	1.90	5.07	5.23	5.41	5.59	5.53	5.36

(Unit : ₱ x 10^3)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
I. Source of Funds										
A. Internal Cash Generation										
A-1 Income	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534
A-2 Depreciation	1,035,629	1,035,629	1,035,629	1,035,629	1,035,629	1,035,629	1,035,629	1,053,629	1,035,629	1,035,629
B. Foreign Borrowing										
C. Equity Contribution										
TOTAL SOURCE OF FUNDS	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163
II. Application of Funds										
A. Addition to Plant/Transmission Line										
B. Project										
B-1 Interest during Construction										
B-2 Operating Interest	46,390	42,822	39,253	35,685	32,116	28,548	24,979	21,411	17,842	14,274
B-3 Principal Repayment	118,950	118,950	118,950	118,950	118,950	118,950	118,950	118,950	118,950	118,950
C. Power Plants & Associated Transmission										
C-1 Interest during Construction										
C-2 Operating Interest	395,489	360,912	326,337	291,759	257,180	222,607	191,896	161,184	130,476	104,672
C-3 Principal Repayment	550,093	550,093	550,093	550,092	550,091	502,344	502,344	502,344	444,631	373,224
TOTAL APPLICATION OF FUNDS	1,110,922	1,072,777	1,034,633	996,486	958,337	872,449	838,169	803,889	711,899	611,120
III. Cash Excess (Deficit)	5,219,241	5,257,386	5,295,530	5,333,677	5,371,826	5,457,714	5,491,994	5,526,274	5,618,264	5,719,043
Debt Service Ratio	5.70	5.90	6.12	6.35	6.61	7.26	7.55	7.87	8.89	10.36

(Unit : ₱ x 10^3) (4/4)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
I. Source of Funds										
A. Internal Cash Generation										
A-1 Income	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534	5,294,534
A-2 Depreciation	1,035,629	1,035,629	1,035,629	1,035,629	1,035,629	1,035,629	1,035,629	1,035,629	1,035,629	1,035,629
B. Foreign Borrowing										
C. Equity Contribution										
TOTAL SOURCE OF FUNDS	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163	6,330,163
II. Application of Funds										
A. Addition to Plant/Transmission Line										
B. Project										
B-1 Interest during Construction										
B-2 Operating Interest	10,705	7,137	3,568							
B-3 Principal Repayment	118,950	118,949	118,949							
C. Power Plants & Associated Transmission										
C-1 Interest during Construction										
C-2 Operating Interest	84,941	69,632	54,326	39,016	27,274	19,863	14,815	9,769	4,723	1,219
C-3 Principal Repayment	294,894	294,893	294,892	250,921	197,365	168,198	168,198	168,198	116,718	40,708
TOTAL APPLICATION OF FUNDS	509,490	490,611	471,735	289,937	224,639	188,061	183,013	177,967	121,441	41,927
III. Cash Excess (Deficit)	5,820,673	5,839,552	5,858,428	6,040,226	6,105,524	6,142,102	6,147,150	6,152,196	6,208,722	6,288,236
Debt Service Ratio	12.42	12.90	13.42	21.83	28.18	33.66	34.59	35.57	52.16	150.98

10. THE EXECUTING AGENCY

10.1. History of the Executing Agency NAPOCOR

The National Power Corporation (NAPOCOR) started in 1936 as a non-stock government corporation with a very limited means to finance its capital-intensive projects. The government later authorized NAPOCOR to float bonds and borrow from international financing institutions to enable it to pursue its program of national electrification. It is now a stock corporation whose shares are wholly owned by the government. Recently, its capital stock was raised to ₱50 billion.

Pursuant to the declaration of national policy under Republic Act No. 6395 and Presidential Decree No. 40, the development of power from all sources has been entrusted to NAPOCOR to meet the needs of national electrification on area coverage basis. This includes the setting up of transmission line grids and the construction of the associated generation facilities.

10.2. Outline of the Whole NAPOCOR Organization

Per requirements of the New Charter and increased responsibilities under the New Society, the Corporation was recently reorganized to operate through seven (7) offices, namely:

1. Office of the President
2. Office of the Senior Vice President
3. Office of the Vice-President for Corporate Planning
4. Office of the Vice-President for Engineering
5. Office of the Vice-President for Utility Operations
6. Office of the Vice-President for Finance
7. Office of the Vice-President for Human Resources and General Services

The organization chart of NAPOCOR is shown on Table 10-1.

The manpower growth and distribution of NAPOCOR are illustrated in Fig.10-1.

10.3. Role of Each Section Connected with the Project

The role of each section connected with the Project is defined below.

1) System Planning Department and Economics Department, Office of the Vice President for Corporate Planning.

   Responsible for load forecast and system planning.

2) Projects Development Department, Office of the Vice President for Engineering -

   Responsible for a feasibility study of a priority project identified in the system planning.

3) Project Design Department, Office of the Vice President for Engineering -

   Responsible for preparation of contract drawings and tender documents.

4) Manager of Transmission Projects for Luzon, Project Management Department, Office of the Vice President for Engineering -

   Responsible for assessment of tenders, management of contracts, supervision of construction and commissioning in the field.

Table 10-1 Organization Chart of National Power Corporation

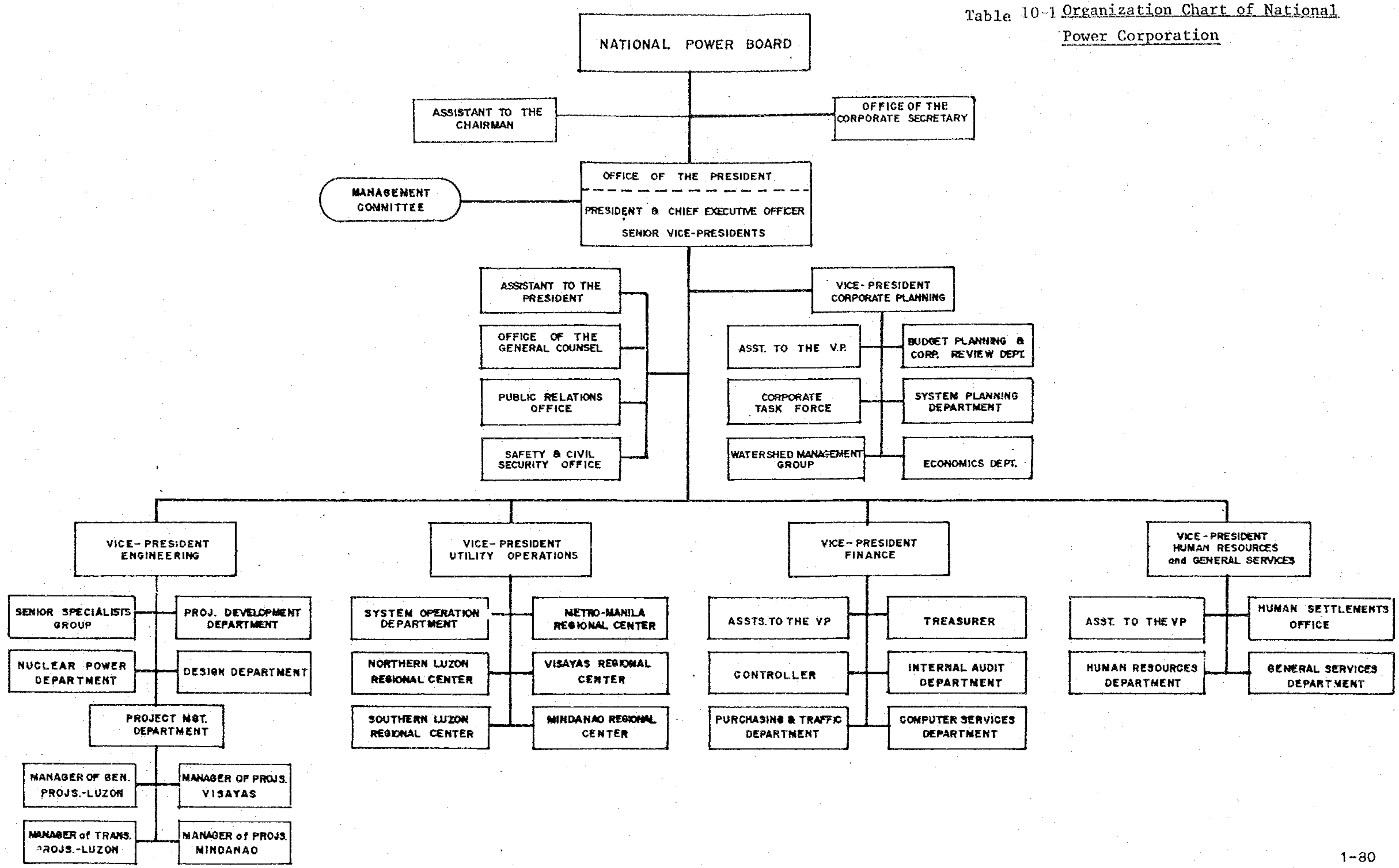
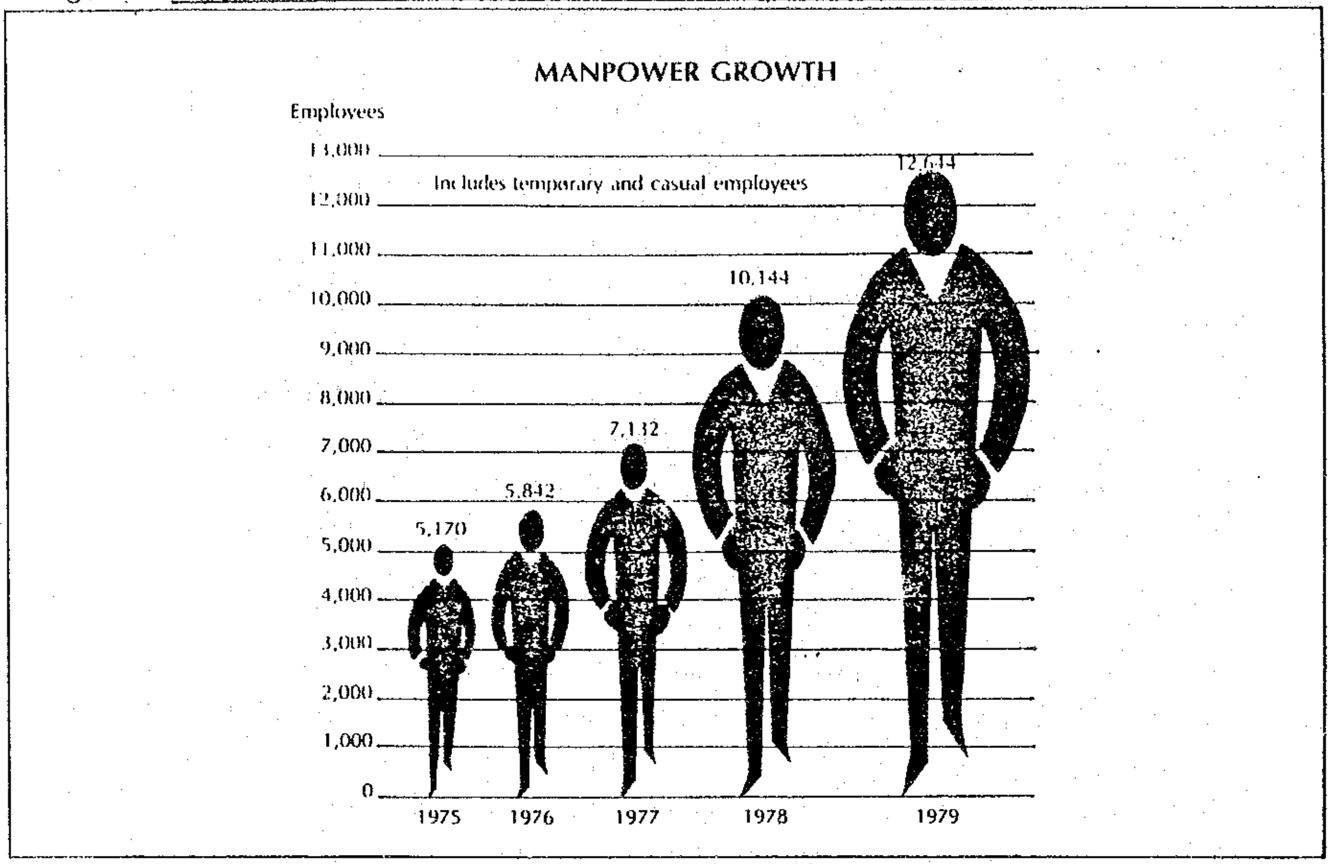
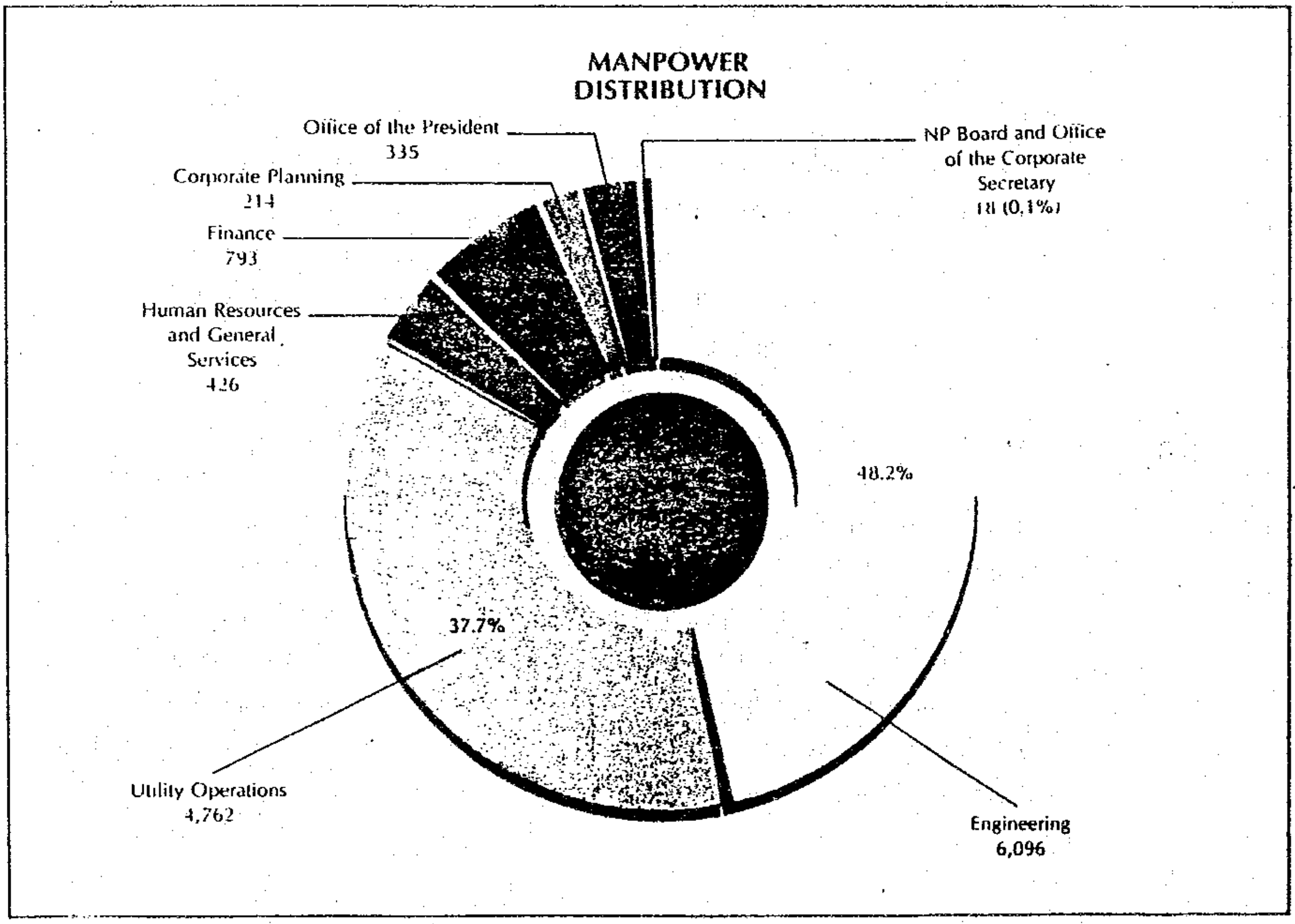


Fig. 10-1 Manpower Growth and Distribution of National Power Corporation





APPENDIX 1

LIGHTNING SHIELDING THEORY BY ARMSTRONG - WHITEHEAD

(1) Lightning Shielding Theory

Previously geometrical analysis was a predominant method in the lightning shielding theory. In recent years, however, probability analysis in which lightning mechanism is taken into consideration has been introduced to the shielding theory. One of the typical theories is represented by the Armstrong - Whitehead theory. Presently, internationally prevalent lightning shielding design of EHV class transmission lines is based on this theory.

The principal factors supporting the Armstrong - Whitehead theory are striking distance, critical stroke current, and angle of lightning stepped leader. The shielding effect and the rate of shielding failure can be comported in use of these factors. Resume of this Armstrong - Whitehead theory is given below :

Striking Distance

a) Lightning discharge occurs when the lightning stroke is initiated by a streamer from the cloud which progresses toward the earth in a series of steps of lightning leader, and upon reaching the earth a return stroke to the croud takes place accompanying a large current string spark and thunder.

b) In the initial stage of lightning discharge, stepped leader with pilot streamer progresses toward the earth at the interval of approx. 50 μs and at the velocity of about 50 m/μs. Upon reaching near to the earth (about 100 m above the ground), discharge object on the earth is determined, from which a connecting streamer occurs. The distance between the stepped leader and the discharge object is called as a striking distance, and can be expressed as a function of lightning stroke current I_o in the following equation:

$$\hat{r}_s = 6.0\ I_o^{0.8} \qquad \text{(A-1)}$$

$\hat{r}_s$: Effective striking distance mm

$= \bar{r}_s - \sigma = 0.9\,\bar{r}_s$

$\bar{r}_s$: Mean striking distance $= 6.7\ I_o^{0.8}$

I_o : Stroke current in kA

Critical Stroke Current to Conductor

In the equation (A-1) , the less I_o is the shorter $\hat{r}_s$ is. This means the shielding range of ground wire is small. According a transmission line having higher conductor and ground wires as compared with $\hat{r}_s$ can not be protected completely. (Refer to Fig. 1.) However, there would be no problem if no back flashover to tower is caused at insulator string even though the conductor is stricken directly due to shielding failure. This indicates that transmission shielding design would not be required for the lightning stroke current below the value of I_c represented by the equation below. Namely, the value of I_c is called as critical stroke current to conductor and the shielding design should deal with this critical stroke current.

$$I_c = \frac{E}{Z/2} \qquad \text{(A-2)}$$

where, I_c = Critical stroke current to Conductor (kA)

E : Basic insulation level or 50% impulse flashover voltage of insulator string (kV)

Z : Surge impedance of phase conductor in the presence of shielding wires

Stroke Angle of Lightning Stepped Leader

The previous shielding theories had discussed only the shielding against vertical lightning strokes. These theories would, however, be unable to explain the lightning outage recorded at the lower phases of double circuit vertical configuration transmission lines. Actually, based on the direct stroke outage records, stroke angle of lightning stepped leader to the vertical can be expressed by probable density function as given below :

$$f(\alpha) = Km \cdot Cos^{m} \qquad \text{(A-3)}$$

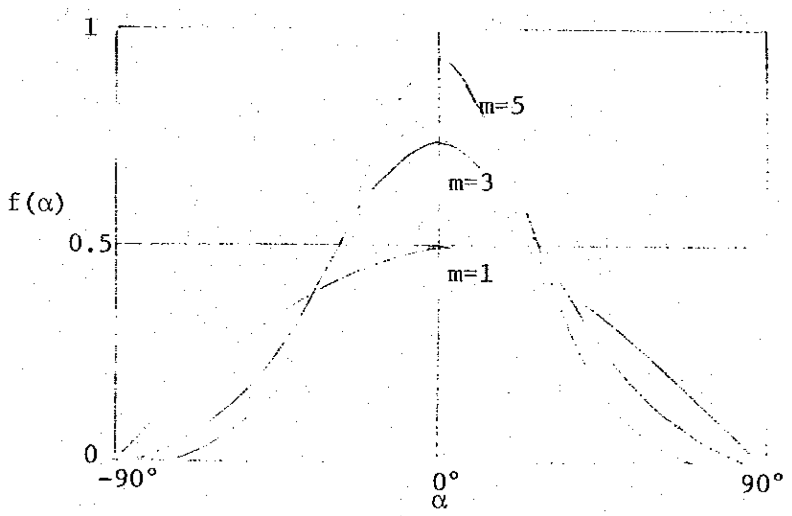
where, $f(\alpha)$: probable density function of stroke angle of lightning stepped leader

: Stroke angel ($-90° \leq \alpha \leq 90°$)

m : Constant ($0 < m < \infty$)

Km : Constant, $\int_{-90°}^{90°} f(\alpha) d\alpha = 1$

The function of $f(\alpha)$ is depicted on the following figure. Where $m = \infty$, $f(\alpha)$ is vertical lightning strokes applied in the previous theories. Currently prevailing figure is $m = 1 \sim 5$.



(2) Effective and Non-effective Shielding Models

Fig. 1 shows the lightning shielding models under the assumption of the same striking distances to shielding wire, phase conductor and the earth.

The distance $\widehat{r}_s$ in (1) of Fig. 1 is the striking distance obtained from Eq. A-1. Here, where the earth is sloped at the gradient of θg, the exposure arc is $\widehat{AB'}$ and where Og = 0, the exposure arc is $\widehat{AB}$. Upon the reaching of lightning leader to this exposure arc, phase conductor is suffered by direct lightning stroke, which is shielding failure. Effective shielding is attained by nullifying the exposure arc $\widehat{AB}$ or $\widehat{AB'}$ in (1) of Fig. 1. Accordingly, ΔASC is rotated clockwise centering the phase conductor C and the shielding wire and phase conductor is arranged so as that the point A agrees with the point B or B'. Effective shielding model with no exposure arc is shown as (2) of Fig. 1.

(3) Effective Shielding Angle

In the effective shielding model represented with (2) of Fig. 1, the conditions of effective shielding is given as below :

$$\bar{\theta}sc \leqq \bar{\theta}g - \sin^{-1}[(\bar{Y}/\hat{r}_s)\mathrm{Cos}\bar{\theta}g - 1] - \beta \qquad \text{(A-4)}$$

$\bar{\theta}sc$: Effective shielding angle

θg : Mean ground angle

$\bar{Y}$: Mean height of phase conductor C

$\hat{r}_s$: Effective striking distance between lightning stroke leader and shielding wire S, phase conductor C, the ground ($= 0.6\ I_c^{0.8}$)

β : $\sin^{-1}(\bar{C}/2\hat{r}_s)$

$\bar{C}$: Distance between shielding wire S and phase conductor C

(4) Shielding Failure Rate

The shielding failure rate can be obtained by the following integration, with respect to the exposure are shown in (1) of Fig. 1.

$$P = \int_{rc}^{Rc} P(r) \int_{\theta_2}^{\theta_1}\int_{\alpha_1}^{\alpha_2} f(\alpha)\,\hat{r}_s\, d\alpha\, d\theta dr \qquad \text{(A-5)}$$

where, r_c : Lower critical value of striking distance

R_c : Upper value at which the exposure becomes zero

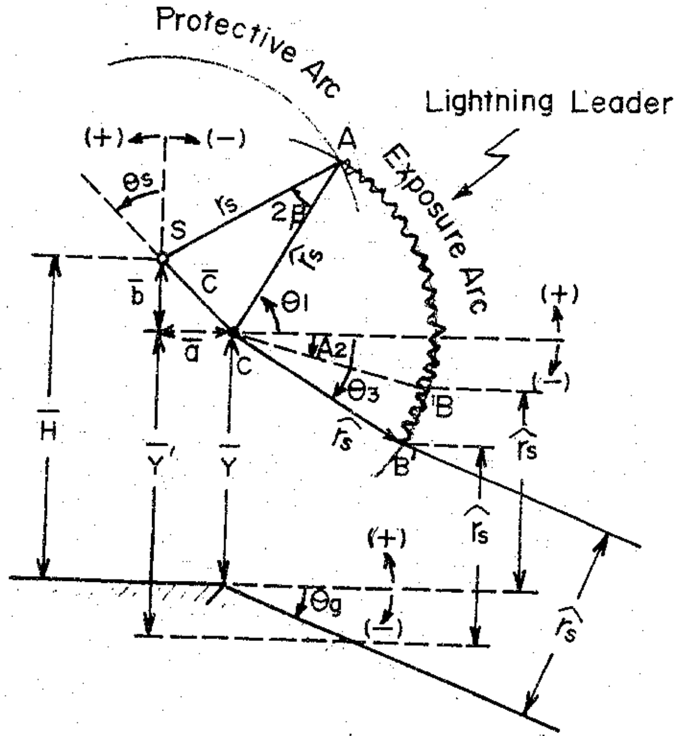
$P(r)$: Percentage of strokes which are shielding failures
The following approximation is used by Armstrong :

$$P(i) = 0{,}475e^{-i/20} + 0.1e^{-i/50} \qquad \text{(A-6)}$$

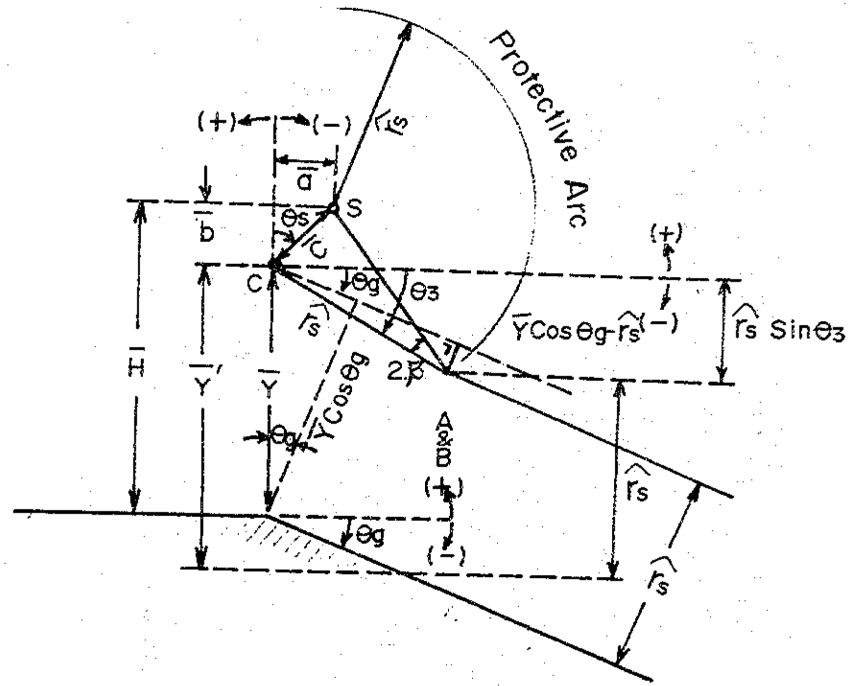
In the equation (A3-5), $\iint f(\alpha)\hat{r}_s d\alpha d\theta$ is obtained assuming m = 1 for $f(\alpha) = K m \cos^m\alpha$ as follows :

$$\frac{\hat{r}_s}{2}(\cos\theta_2 - \cos\theta_1 + \theta_1 - \theta_2) \qquad \text{(A-7)}$$

The products of Equations (A-6) and (A-7) are obtained with a proper value of lightning current increase Δi and are summed up to arrive at the approximate shielding failure rate.



(1) Model of Non-Effective Shielding



(2) Model of Effective Shielding

Fig. 1. Lightning Shielding Models

APPENDIX 2

TEMPERATURE RISE ON CONDUCTOR CAUSED BY 1CCT TRIP-OUT (SHORT-TIME CURRENT-CARRYING CAPACITY)

(1) Heat-balance Equation of Conductor

Heat-balance equation is as follows :

$$I^2\gamma + Ws.\eta d = (hw + \eta hr)\ \pi d\theta \qquad \text{(A-1)}$$

The left side(P) of the above equation indicates head generation and heat absorption (accumulated heat) in the conductor, while the right side (Q) represents heat emission (convected and radiated heat) of the conductor. At steady state, both is kept balanced (P = Q).

At the transient state, following defferencial equation is concluded:

$$\frac{d\theta}{dt} = \frac{P-Q}{C} \qquad \text{(A-2)}$$

Reforming this equation, following approximation is obtained:

$$\Delta\theta = (P-Q)\frac{\Delta t}{C} \qquad \text{(A-3)}$$

where, θ = Temperature of the conductor (°C)
t = Time (minutes)
C = Thermal rating of the conductor (watt. min./cm.°C)
(ACSR795MCM - 9.25 w-sec./cm.°C)

(2) P-Q Characteristic of ACSR 795 MCM

Fig. 1 shows P and Q as a function of temperature rise on Conductor.

P : Accumulated heat in conductor

$$= I^2\gamma[1+\alpha(\theta+T-20)] \times 10^{-5} + Ws.\eta d \ [w/cm] \qquad \text{(A-4)}$$

Q : Convected and radiated heat in conductor

$$= (hw + \eta hr)\ \pi d\theta \ [w/cm] \qquad \text{(A-5)}$$

Equation (A-5) is the function of Q only.

$$\text{Now } Q = \frac{0.002427}{(313+\frac{\theta}{2})^{0.123}} + 0.0005184 \frac{(\frac{313+\theta}{100})^4 - 95.979}{\theta} \times 8.72106\ \theta \qquad \text{(A-6)}$$

θ :	30°	60	90	120	150
Q :	0.5032	1.0605	1.6827	2.3813	3.1686

And, Equation (A-4) is the function of Q and I. P is shown on Fig. 1 in case of I = 200 ∿ 1800.

$$P = 0.719 \times 10^{-6}\ I^2[1.08 + 0.004\theta] + 0.2498 \qquad \text{(A-7)}$$

I	0°	30°	60°	90°	120°	150°
200	0.281	0.284	0.288	0.291	0.295	0.298
400	0.374	0.388	0.402	0.415	0.429	0.443
600	0.529	0.560	0.581	0.623	0.654	0.685
800	0.747	0.802	0.857	0.912	0.968	1.023
1000	1.026	1.113	1.199	1.285	1.371	1.458
1200	1.368	1.492	1.616	1.741	1.865	1.989
1400	1.772	1.941	2.110	2.279	2.448	2.617
1600	2.238	2.459	2.679	2.900	3.121	3.342
1800	2.766	3.045	3.325	3.604	3.884	4.163

The difference P-Q in Equation (A-3) is expressed by:

$$P-Q = \Delta\theta \frac{C}{\Delta t} = \frac{0.154\Delta\theta}{\Delta t} \qquad \text{(A-8)}$$

C = 9.25 [w.sec/°C.cm] = 0.154 [w.min/°C-cm]

Δt = 1, 2.5, 5, 10 min.

P-Q obtained in Equation (A-8) is illustrated on Fig. 1.

(3) Temperature Rise on Conductor at 1cct Trip-out

Assuming that each phase conductor of 2 circuit line is carrying 80% of continuous current-carrying capacity (820 x 0.80 = 655A) and due to the trip-out of one circuit, the remaining circuit is loaded at the current equivalent to 160% of said capacity (820 x 1.60 = 1,310A), the temperature on the conductor rose as the time elapes is computed in use of Fig. 1.

1) Before the trip-out takes place, the temperature is obtained from the intersection of I = 655A and Q., i.e.

$$\theta = 37°C \ (\theta+T = 37 + 40 = 77°C)$$

2) At t = 0, I = 1,310A(80 → 160%),

3) under t = 1 (min) and θ = 37°C,

$$P = 1.77 \text{ w/cm}$$
$$Q = 0.63 \text{ w/cm}$$
$$P-Q = 1.14 \text{ w/cm}$$

Seeing P-Q at Δt = 1, the temperature is 7.3°C, θ = 37 + 7.3 = 44.3°C

(Q + T = 44.3 + 40 = 84.3°C)

4) at t = 2 (min) and θ = 44.3°C

$$P = 1.80$$
$$Q = 0.75$$
$$P-Q = 1.05$$

at Δt = 1, Δθ = 6.8°C

θ = 44.3 + 6.8 = 51.1°C

(Q + T = 51.1 + 40 = 91.1°C)

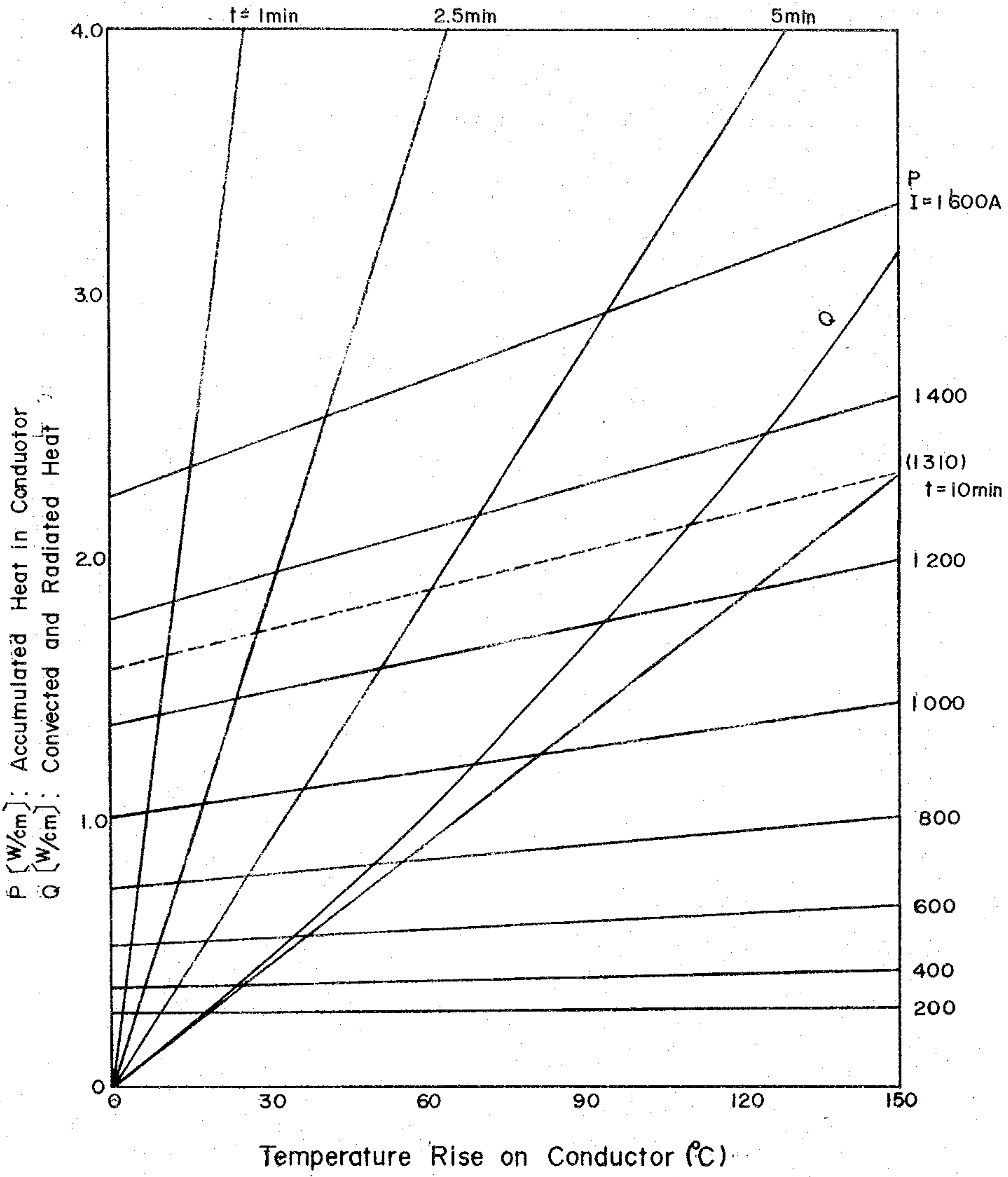


Fig. 1. P-Q Characteristic (ACSR 795MCM)

By repeating the same procedure, the following table is derived and it is illustrated on Fig. 2.

Likewise, the cases of 90 - 180%, 75 - 150%, 70 → 140% and 65 → 130% can be computed. The results are also shown on Fig. 2.

Time[min.]	P[w/cm]	Q[w/cm]	P-Q	Δt:Δθ	θ°C	θ+T°C
0					37.0	77.0
1	P_{37} = 1.77	Q_{37} = 0.63	1.14	1: 7.3	44.3	84.3
2	$P_{44.3}$ = 1.80	$Q_{44.3}$ = 0.75	1.05	1: 6.8	51.1	91.1
3	$P_{51.1}$ = 1.84	$Q_{51.1}$ = 0.88	0.96	1: 6.1	57.2	97.2
4	$P_{57.2}$ = 1.87	$Q_{57.2}$ = 1.00	0.87	1: 5.5	62.7	102.7
5	$P_{62.7}$ = 1.90	$Q_{62.7}$ = 1.10	0.80	1: 5.0	67.7	107.7
10	$P_{67.7}$ = 1.92	$Q_{67.7}$ = 1.20	0.72	5:23.2	90.9	130.9
15	$P_{90.9}$ = 2.04	$Q_{90.9}$ = 1.70	0.34	5:11.0	101.9	141.9
20	$P_{101.9}$ = 2.09	$Q_{101.9}$ = 1.95	0.14	5: 4.5	106.4	146.4
25			0.06	5: 2.0	108.4	148.4
30	$P_{106.4}$ = 2.11	$Q_{106.4}$ = 2.05	0.06	10: 3.6	110.0	150.0
40	P_{110} = 2.13	Q_{110} = 2.13	0	10: 0	110.0	150.0

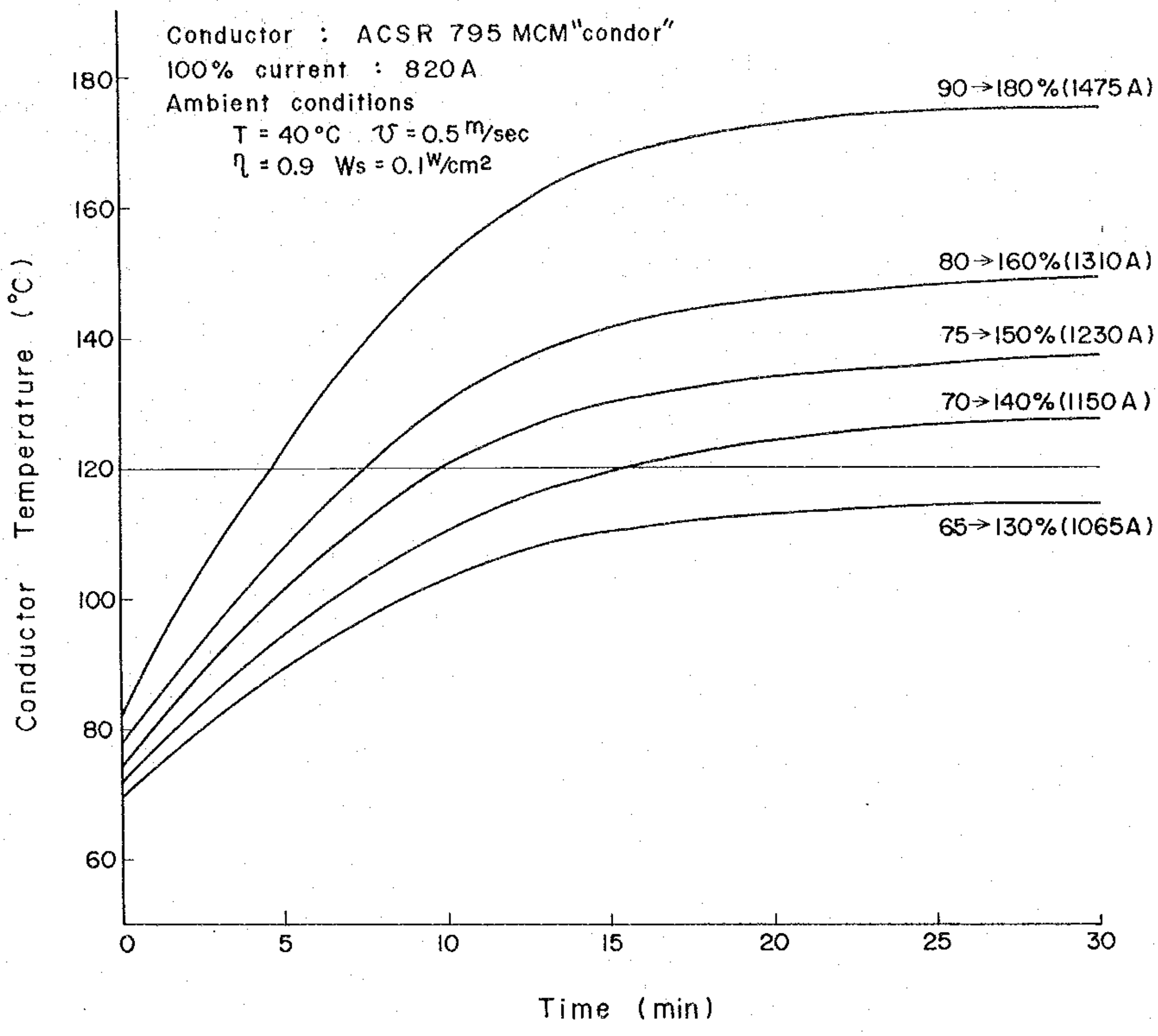


Fig. 2, Temperature Rise on Conductor Caused by Icct Trip-Out

APPENDIX 4 COMPARISON OF CONSTRUCTION COST

Item	Construction Cost (%)	
	Double Circuit	Single Circuit
Steel tower	100	70
Insulators accessories	100	50
Conductors, ground wires	100	55
Tools, equipment rental	100	80
Subtotal: material	100	61
Erection of towers	100	80
Stringing works	100	75
Subtotal: work	100	79
Right of Way	100	92
Total Direct Cost	100	68