A-2 EXAMINATION OF DESIGN SEISMIC COEFFICIENTS FOR POECHOS AND CURUMUY HYDROELECTRIC POWER PROJECT SITES

A-2 EXAMINATION OF DESIGN SEISMIC COEFFICIENTS FOR POECHOS AND CURUMUY HYDROELECTRIC POWER PROJECT SITES

1. POECHOS SITE

From the earthquake observation records of the neighborhood of the Poechos site (see Fig.-13), earthquake motion accelerations are calculated, the annual maximum accelerations are extracted, and the average value (m) and standard deviation (σ) are determined.

The maximum acceleration (α_m), from Okamura's formula is

$$\log_{10} \frac{\alpha_m}{640} = \frac{D + 40}{100} (-7.604 + 1.7244\ M - 0.1036\ M^2)$$

where

α_m : maximum dynamic acceleration (gal)

D : epicentral distance (km)

M : magnitude

The earthquake observation records used for these calculations and the results of calculations are given in Table A-2-1.

Table A-2-1 Maximum Dynamic Acceleration

No.	Date Recorded			Epicentral Distance (km)	Magnitude (M)	Dynamic Acceleration (Max.) (gal)
	Day	Mon.	Yr.			
1	09	09	1923	67	4.80	9
2	29	12	33	116	5.18	3
3	15	09	37	37	4.98	39
4	06	02	45	50	4.92	22
5	20	02	48	50	4.23	3
6	16	10	50	50	3.94	4
7	20	09	51	95	4.21	1
8	19	08	54	170	4.78	0
9	14	06	55	70	3.95	1
10	17	08	56	65	5.00	14
11	07	02	59	133	7.25	70
12	04	05	61	78	5.51	21
17	20	09	62	19	5.92	159
23	20	12	63	68	5.20	18
27	19	09	64	118	4.80	1
29	13	08	65	60	5.10	20
34	28	03	66	81	5.50	21
36	28	03	67	64	4.40	6
39	07	11	68	60	4.80	12
43	30	03	69	30	4.50	28
50	11	12	70	84	5.70	24
63	11	06	71	58	5.40	32
64	25	06	72	39	4.90	32

The average value (m) and standard deviation (σ) are computed from the 23 calculated values above.

Table A-2-2 Frequency Distribution of Maximum Dynamic Accelerations

Dynamic Acceleration (Max.) (gal) (1)	Frequency (2)	(1) × (2)	$(1)^2$
0	1	0	0
1	3	3	1
3	2	6	9
4	1	4	16
6	1	6	36
9	1	9	81
12	1	12	144
14	1	14	196
18	1	18	324
20	1	20	400
21	2	42	441
22	1	22	484
24	1	24	576
28	1	28	784
32	2	64	1,024
39	1	39	1,521
70	1	70	4,900
159	1	159	25,281
Total	23	540	36,218

$$m = \frac{\Sigma (1) \times (2)}{\Sigma (1)} = \frac{540}{23} = 23.5$$

$$\sigma^2 = \frac{\Sigma (1)^2}{\Sigma (2)} - m^2$$

$$\sigma = \frac{36{,}218}{23} - (23.5)^2 = 1{,}002.4$$

$$\sigma = 32.0$$

As the probability density function, on applying an exponential distribution,

$$p(x) = \frac{1}{\sigma} e^{-x/\sigma}$$

where

σ : standard deviation

The probability density function p(x) when maximum dynamic acceleration is x will be

$$p(x) = \frac{1}{32.0} e^{-x/32.0}$$

On seeking the maximum dynamic acceleration x_1 in the range of 99.7% probability, x_1 obtained by solving

$$\int_0^{x} p(x)dx = 0.997$$

will be produced by the following definite integral:

$$\int_0^{x'} p(x)dx = \int_0^{x'} \frac{1}{32.0} e^{-x/32.0} dx = 0.997$$

The result will be x = 177.4 (gal).

To determine the probable number of years for x_1 to recur:

$$x_1 = 2.3\,\sigma\,(\log_{10} t + \log_{10} N_1)$$

where

x_1 : maximum dynamic acceleration

t : probable number of years

N_1 : average number of earthquakes occurring in 1 year (N_1 = 5)

$177.4 = 2.3 \times 32.0 \times (\log_{10} t + \log_{10} 5)$

t = 51 years

Based on the above results, the design seismic coefficient will be the following:

$$K = \frac{x_1}{g} = \frac{177.4}{980} = 0.2$$

2. CURUMUY SITE

Earthquake motion accelerations are calculated from the earthquake observation records of the neighborhood of the Curumuy site (see Fig.-13), and the same procedure as for the Poechos site is followed.

The observation records and calculated values are given in Table A-2-3.

Table A-2-3 Maximum Dynamic Acceleration

No.	Date Recorded			Epicentral Distance (km)	Magnitude (M)	Dynamic Acceleration (Max.) (gal)
	Day	Mon.	Yr.			
1	09	09	1923	74	4.80	7
2	29	12	33	92	5.18	8
3	15	09	37	18	4.98	77
4	06	02	45	16	4.92	78
5	20	02	48	13	4.23	46
6	16	10	50	13	3.94	33
7	20	09	51	111	4.21	0
8	19	08	54	183	4.78	0
9	14	06	55	75	3.95	1
10	17	08	56	71	5.00	12
11	07	02	59	145	7.25	62
13	23	11	61	58	5.94	65
18	26	07	62	36	5.82	97
23	20	12	63	60	4.10	72
27	19	09	64	76	4.80	7
32	18	06	65	5	4.20	66
35	-	10	66	44	4.40	13
37	28	03	67	28	4.40	27
39	07	11	68	100	4.80	3
43	30	03	69	81	4.50	3
51	29	12	70	128	5.80	10
63	11	06	71	92	5.40	12
64	25	06	72	19	4.90	69

Table A-2-4 Frequency Distribution of Maximum Dynamic Accelerations

Dynamic Acceleration (Max.) (gal) (1)	Frequency (2)	(1) × (2)	$(1)^2$
0	2	0	0
1	1	1	1
3	2	6	9
7	2	14	49
8	1	8	64
10	1	10	100
12	2	24	144
13	1	13	169
27	1	27	729
33	1	33	1,089
46	1	46	2,116
62	1	62	3,844
65	1	65	4,225
66	1	66	4,356
69	1	69	4,761
72	1	72	5,184
77	1	77	5,929
78	1	78	6,084
97	1	97	9,409
Total	23	768	48,262

The average value (m) and standard deviation (σ) are

$$m = \frac{\Sigma\,(1)\times(2)}{\Sigma\,(1)} = \frac{768}{23} = 33.4$$

$$\sigma^2 = \frac{\Sigma\,(1)^2}{\Sigma\,(2)} - m^2$$

$$= \frac{48,262}{23} - (33.4)^2 = 983.4$$

$$\sigma = 31.4$$

The probability density function is

$$p(x) = \frac{1.}{\sigma}\, e^{-x/\sigma}$$

$$= \frac{1}{31.4}\, e^{-x/31.4}$$

$$\int_0^{x_1} p(x)dx = \int_0^{x_1} \frac{1}{31.4}\, e^{-x/31.4}\, dx = 0.997$$

The result will be x_1 = 184.4 (gal). The probable number of years "t" will be

$$184.4 = 2.3 \times 31.4 \times (\log_{10} t + \log_{10} 5)$$

$$t = 72 \text{ years}$$

Therefore, the seismic coefficient "K" will be

$$K = \frac{\alpha}{g} = \frac{184.4}{980} = 0.2$$

A-3 STABILITY STUDY OF EXISTING BOTTOM OUTLET OF POECHOS DAM TO BE UTILIZED FOR POECHOS HYDROELECTRIC POWER GENERATION

A - 3 STABILITY STUDY OF EXISTING BOTTOM OUTLET OF POECHOS DAM TO BE UTILIZED FOR POECHOS HYDROELECTRIC POWER GENERATION

The headrace of Poechos Power Station is to consist of the bottom outlet of the existing Poechos Reservoir and a penstock to be newly installed connecting to the end of the bottom outlet.

The existing bottom outlet has a total length (to the branching point) of 389.61 m composed of an orifice section (length 45.30 m), concrete culvert section (inside diameter 8.00 m, length 102.74 m) and a steel pipesection (inside diameter 4.50 m, length 241.44 m), and has the capacity to discharge a maximum 300 m^3/sec.

The penstock of Poechos Power Station to be connected to this bottom outlet is to have a total length of 70.2 m and inside diameter of 3.20 m (2.50 m at the end).

If there were to be a sudden shut-down at Poechos Power Station the water pressure in the existing bottom outlet will rise because of the resulting water-hammer pressure, and therefore, a study will be made of the safety of the existing bottom outlet against this pressure rise.

1. Water Pressure Rise Caused by Water-Hammer Pressure

1.1 Calculation of Water-Hammer Pressure

The problem was solved by the approximation method preparing a general equation regarding a single pipeline for each pipeline, applying the boundary conditions corresponding to the waterway system and making calculations for minute lengths of time based on the initial conditions for each case. An electronic computer was used for the calculations.

The calculations were made under the conditions below for high water level, 95 % low water level and flooding, respectively. The guide vane closing time characteristics were taken to be linear closing and the time was varied between 5 sec. and 20 sec. The time interval for calculations was made 0.01 sec.

(1) High Water Level

Poechos Reservoir water level	103.00 m
Power station discharge level	61.10 m
Total discharge of 2 turbines	22.30 m^3/sec.

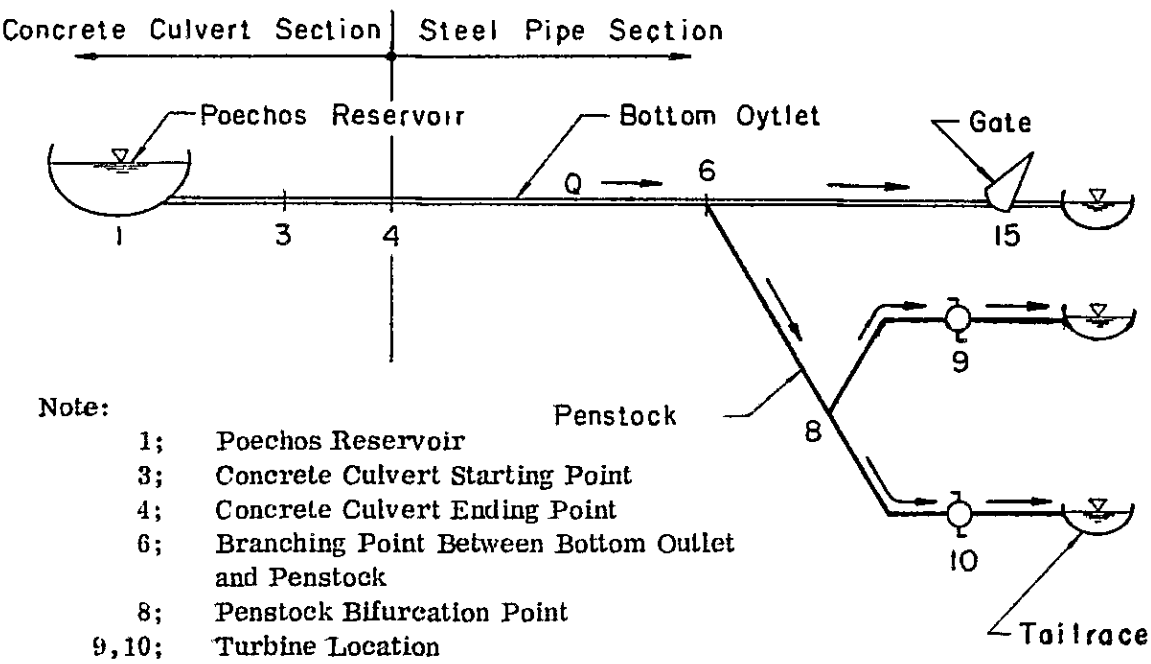
(2) 95 % Water Level

Poechos Reservoir water level	86.30 m
Power station discharge level	61.10 m
Total discharge of 2 turbines	44.20 m^3/sec.

(3) Flooding

Poechos Reservoir water level	103.00 m
Power station discharge level	61.10 m
(a) 100.00 m^3/sec. Inflow	
Diversion to turbines	24.50 m^3/sec.
Diversion to bottom outlet	75.50 m^3/sec.
(b) 200.00 m^3/sec. Inflow	
Diversion to turbines	36.00 m^3/sec.
Diversion to bottom outlet	164.00 m^3/sec.
(c) 300.00 m^3/sec. Inflow	
Diversion to turbines	44.20 m^3/sec.
Diversion to bottom outlet	255.80 m^3/sec.

Fig.- A-3-1 Waterway System Network



Note:

1; Poechos Reservoir
3; Concrete Culvert Starting Point
4; Concrete Culvert Ending Point
6; Branching Point Between Bottom Outlet and Penstock
8; Penstock Bifurcation Point
9,10; Turbine Location
15; Radial Gate Location

1.1.1 Calculation Results

As a result of calculations, the head rise (△ H) and maximum head (H) at the various points are as shown in Tables A-3-1 and A-3-2. Graphically indicated, these are as shown in Figs. A-3-2, A-3-3 and A-3-4.

Table-A-3-1. Head Rises (△H) at Various Points (Closing Time T = 5.0 sec.)

Point	High Water Level Q = Q1 22.3 (m^3/s) △H (m)	95% Low Water Level Q = Q1 44.2 (m^3/s) △H (m)	Flooding Q = 100 (m^3/s) Q1 = 24.5 (m^3/s) △H (m)	Flooding Q = 200 (m^3/s) Q1 = 36.0 (m^3/s) △H (m)	Flooding Q = 300 (m^3/s) Q1 = 44.2 (m^3/s) △H (m)
3	2.34	5.57	1.13	2.56	4.16
4	4.12	10.67	2.34	3.91	6.84
6	10.84	30.76	10.09	11.26	12.59
8	13.91	40.45	15.66	24.43	39.54
9	15.15	45.01	17.35	27.41	45.15
15	-	-	9.92	10.05	8.38

Table-A-3-2. Maximum Heads (H) at Various Points (Closing Time T = 5.0 sec.)

Point	High Water Level Q1 = Q2 22.3 (m^3/s) H (m)	95% Low Water Level Q1 = Q2 44.2 (m^3/s) H (m)	Flooding Q = 100 (m^3/s) Q1 = 24.5 (m^3/s) H (m)	Flooding Q = 200 (m^3/s) Q1 = 36.0 (m^3/s) H (m)	Flooding Q = 300 (m^3/s) Q1 = 44.2 (m^3/s) H (m)
4	45.55	35.40	43.77	45.34	48.27
6	52.66	55.88	51.91	53.08	54.41
8	58.26	68.10	60.01	68.78	83.89
9	59.85	73.01	62.05	72.11	89.85
15	(50.59)	(53.81)	49.67	49.80	48.13

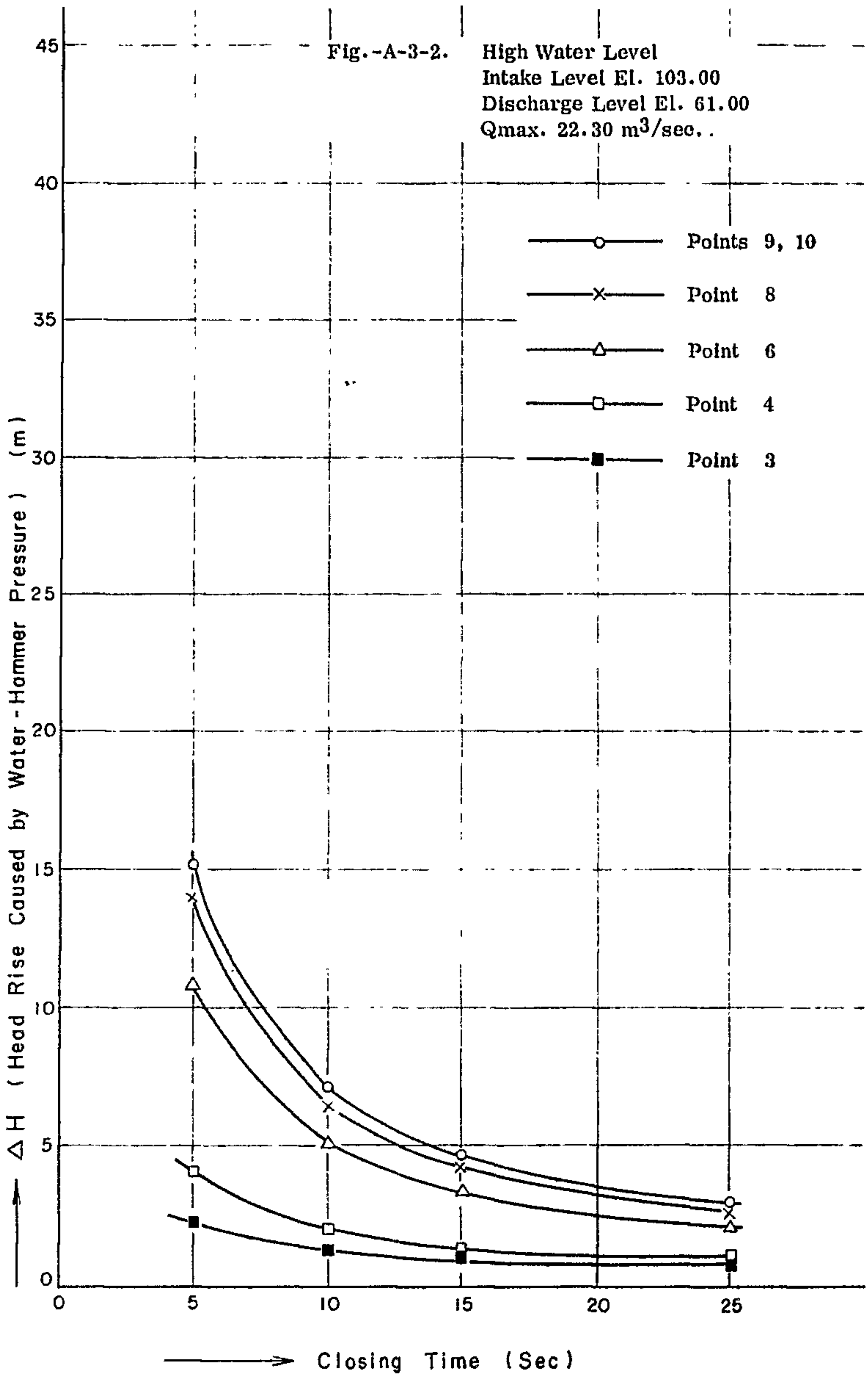


Fig.-A-3-2. High Water Level
Intake Level El. 103.00
Discharge Level El. 61.00
Qmax. 22.30 m3/sec..
Points 9, 10
Point 8
Point 6
Point 4
Point 3
ΔH (Head Rise Caused by Water-Hammer Pressure) (m)
45
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
Closing Time (Sec)

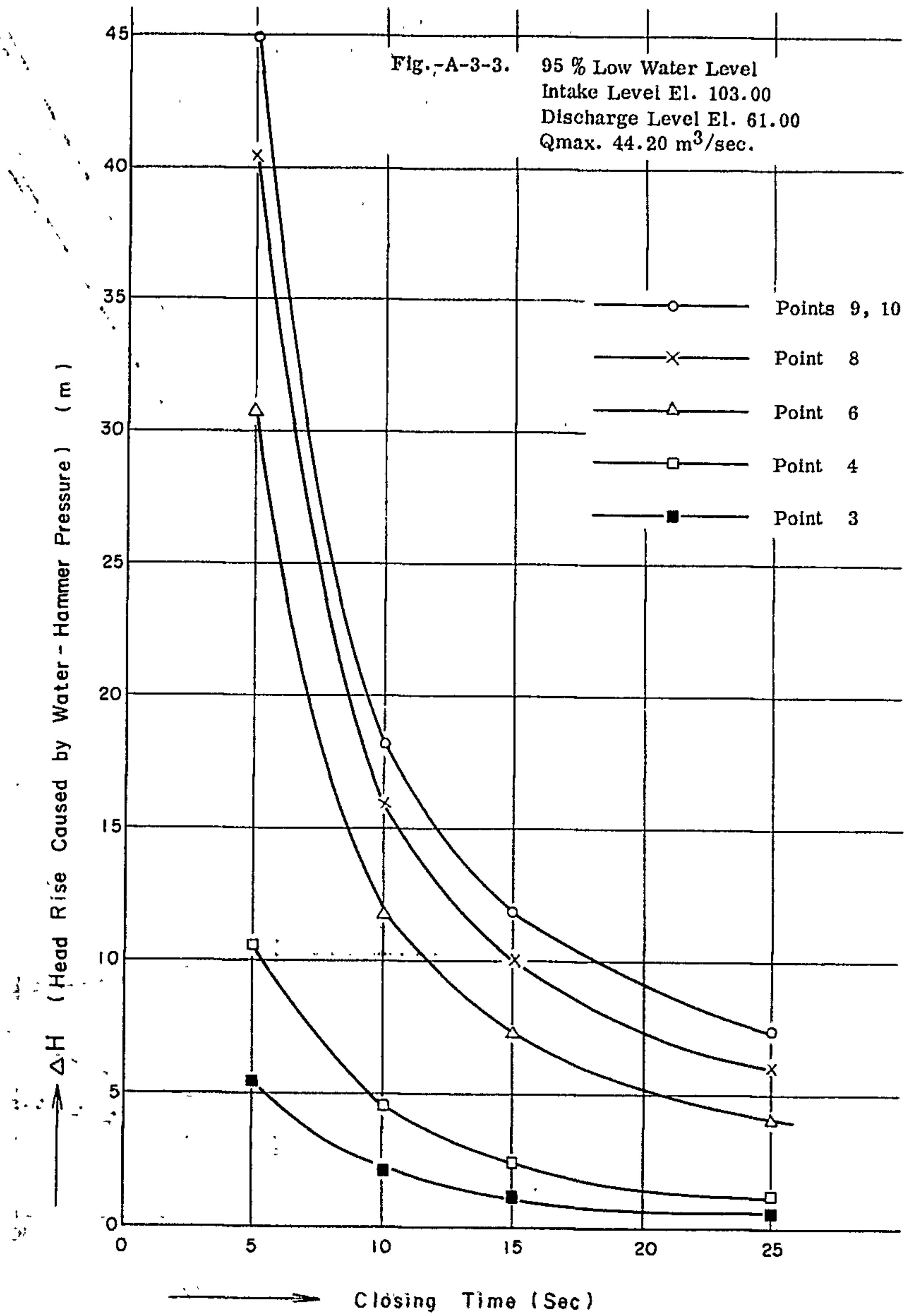


Fig.-A-3-3.
95 % Low Water Level
Intake Level El. 103.00
Discharge Level El. 61.00
Qmax. 44.20 m3/sec.
Points 9, 10
Point 8
Point 6
Point 4
Point 3
ΔH (Head Rise Caused by Water - Hammer Pressure) (m)
Closing Time (Sec)
0
5
10
15
20
25
30
35
40
45

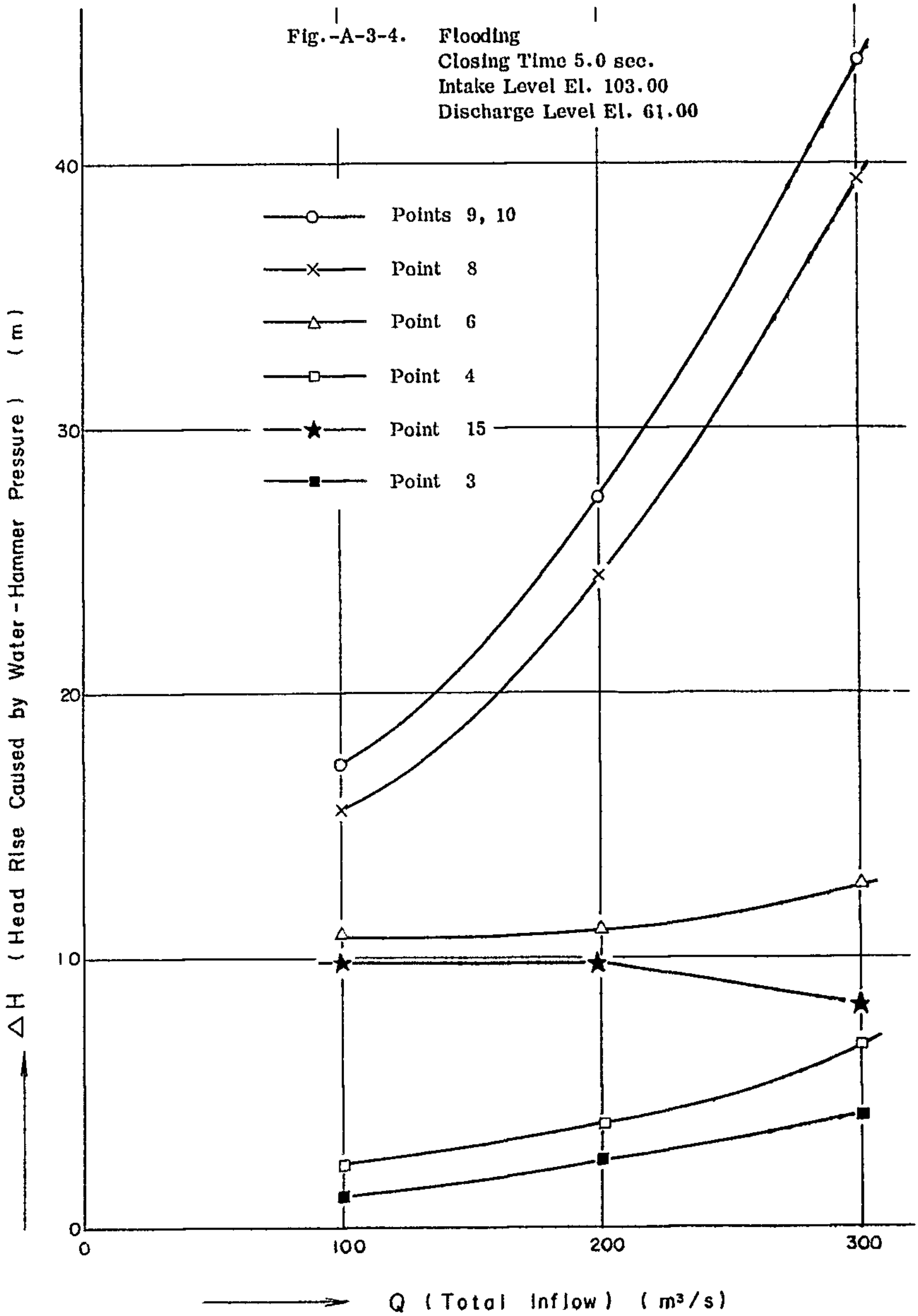
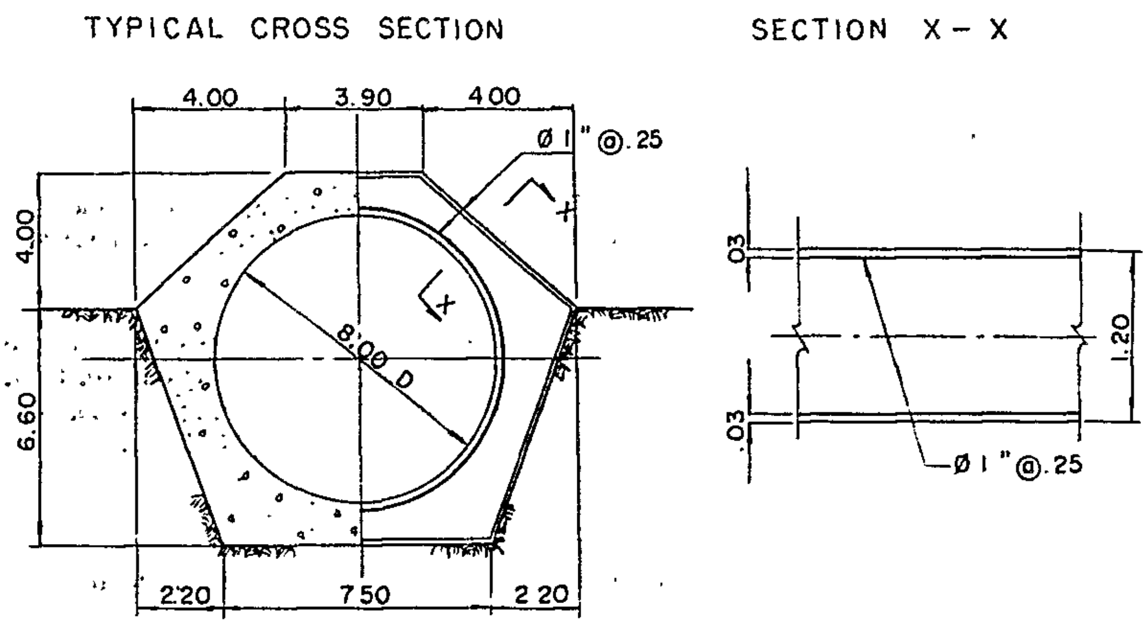


Fig.-A-3-4. Flooding
Closing Time 5.0 sec.
Intake Level El. 103.00
Discharge Level El. 61.00
Points 9, 10
Point 8
Point 6
Point 4
Point 15
Point 3
ΔH (Head Rise Caused by Water-Hammer Pressure) (m)
Q (Total Inflow) (m³/s)
0
10
20
30
40
100
200
300

2. Water Pressure Rise at Culvert Section Caused by Water-Hammer Pressure

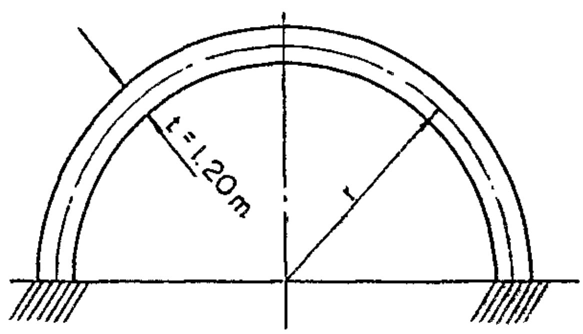
The culvert section is the portion of the bottom outlet connecting the orifice section and the steel pipeline, is buried at the base part of the dam from the center axis of the dam to the upstream toe, and since it is influenced by water-hammer pressures in power station operation, the limit to the allowable internal pressure was studied. The cross section used in calculations is as shown in Fig.-A-3-5.

Fig.-A-3-5. Structure of Culvert Section



In making the calculations, an arch with both ends fixed as shown in Fig.-A-3-6 was assumed and design loads were differentiated for normal times and during earthquakes.

Fig.-A-3-6. Assumed Structure for Calculations



2.1 During Norlam Times

For the study of normal times the following loads were considered.

(1) Internal Pressure

(a) Hydrostatic pressure (including water level rise due to wind)

(b) Water pressure rise ($\triangle$ H) caused by water-hammer pressure

(2) Vertical Load

Dead weight of reinforced concrete

2.1.1 Results of Study

As a result of calculations, the allowable water-hammer pressure of the concrete culvert is ($\triangle$ H) = 10.2 m with allowable stress of reinforcing steel 1,800 kg/cm^2.

However, the water-hammer pressure at the connection between the concrete culvert and the steel pipe sections (Point No. 6) at closing time of 5 sec. is 10.67 m. But this point is located at the central part of the dam and when the weight of the dam applied to the top of the arch is considered, there will be amply safety.

2.2 During Earthquakes

The following loads were considered for the study of the condition during earthquake.

(1) Internal Pressure

(a) Hydrostatic pressure

(b) Water pressure rise caused by water-hammer pressure

(c) Wave height (h_e) at water surface due to earthquake

(d) Dynamic water pressure

(2) Vertical Load

(3) Force due to Inertia of Reinforced Concrete

2.2.1 Results of Study

As a result of calculations, ($\triangle$ H) = 10.3 m with allowable stress of reinforcing steel during earthquake 1,800 × 1.5 = 2,700 kg/cm^2. Therefore, there is ample safety for the same reason as at normal times.

3. Water Pressure Rise at Steel Pipe Section

The study of the steel pipe section was made considering water-hammer pressure due to sudden closing of the turbines at Poechos Power Station during normal times and during earthquakes.

The shape of the cross section used for calculations is as shown in Fig.-A-3-7.

3.1 Normal Times

The following loads were considered in the study of conditions at normal times.

(1) Internal Pressure

(a) Hydrostatic pressure (reservoir water level: 108.00 m)

(b) Water pressure rise caused by water-hammer pressure

(2) Vertical Load

(a) Dead weight of reinforcing concrete

(b) Dead weight of steel pipe

(3) Stress Due to Temperature Variation

(a) Temperature variation of 15° C

(b) Temperature variation due to initial water passage, 10° C

3.1.1 Results of Study

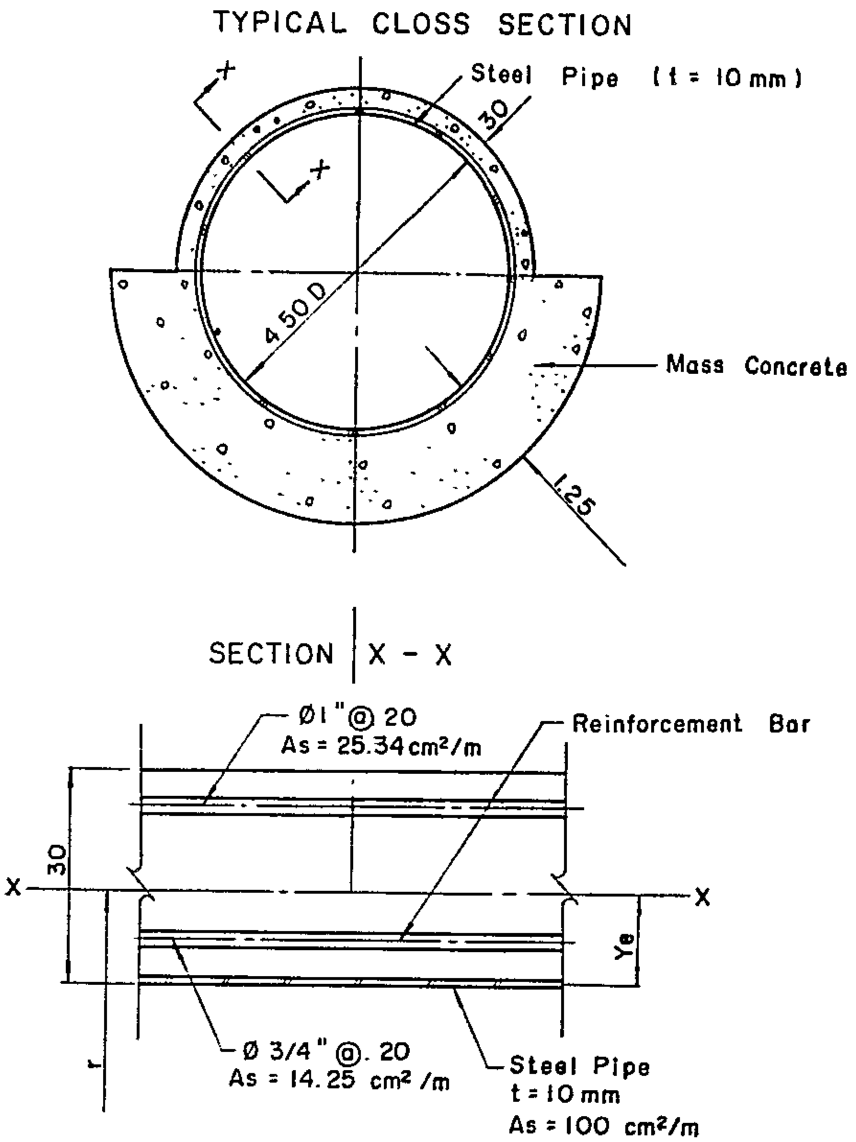
The results of calculations for rapid closing time of 5 sec. are shown in Table-A-3-3. The maximum stress is produced at the arch portion in the ordinary state, the value of which is 1,189 kg/cm^2. Even if stresses due to temperature variation were to be added to this, the maximum would be 1,455 kg/cm^2, and there will be ample safety when seen from the allowable tensile stress of the steel pipe of 2,100 kg/cm^2.

3.2 During Earthquake

The load during an earthquake is the load at normal times to which the inertia forces due to the earthquake are added. The seismic coefficient used here was the value adopted in design of Poechos Dam (K = 0.4, β = 1.6). The loads considered for calculations were the following.

(a) Hydrostatic pressure

Fig.-A-3-7. Structure of Steel Pipe Section



(b) Water weight of reinforcing concrete

(c) Dead weight of reinforcing concrete

(d) Dead weight of steel pipe

(e) Water level rise and dynamic water pressure of reservoir due to earthquake

(f) Inertia force of water inside steel pipe due to earthquake

(g) Inertia force of reinforcing concrete

(h) Inertia force of steel pipe

(i) Stress due to temperature variation

3.2.1 Results of Study

The results of study are as shown in Table-A-3-4. The maximum stress in this case is 2,064 kg/cm^2 and there is ample safety in view of the allowable tensile stress (2,100 × 1.5 = 3,150 kg/cm^2) of the steel pipe.

Based on the above, it is judged that the bottom outlet will be amply safe against rise in water pressure due to sudden closing of 5 sec. at Poechos Power Station.

Table-A-3-3. Stress at Normal

(kg/cm^2)

φ	Stress by load		Stress by temperature				Total (1)		Total (2)	
	σ_{1l}	σ_{2l}	σ_{1t}	σ_{2t}	σ_{1t}'	σ_{2t}'	$\sigma_{1l}+\sigma_{1t}$	$\sigma_{2l}+\sigma_{2b}$	$\sigma_{1l}+\sigma_{1t}'$	$\sigma_{2l}+\sigma_{2t}'$
0°	-1189	936	69	-23	-266	-195	-1120	913	-1455	741
30°	-1135	949	43	-15	-239	-200	-1092	934	-1374	749
60°	-939	997	-30	5	-190	-213	-969	992	-1129	784
90°	-520	1106	-129	33	-124	-232	-649	1139	-644	874
-30°	-1135	949	43	-15	-239	-200	-1092	934	-1374	749
-60°	-939	997	-30	5	-190	-213	-969	992	1129	784
-90°	-520	1106	-129	33	-124	-232	-649	1139	-644	874

σ_{1t}, σ_{2t} ; Temperature variety is + 15°C

σ_{1t}', σ_{2t}' ; Temperature variety is - 10°C and the first stage stress

Table-A-3-4. Stress During Earthquake

(kg/cm^2)

φ	Stress by load		Stress by temperature				Total (1)		Total (2)	
	σ_{1l}	σ_{2l}	σ_{1t}	σ_{2t}	σ_{1t}	σ_{2t}'	$\sigma_{1l}+\sigma_{1t}$	$\sigma_{2l}+\sigma_{2t}$	$\sigma_{1l}+\sigma_{1t}'$	$\sigma_{2l}+\sigma_{2t}'$
0°	-1552	1211	69	-23	-266	-195	-1483	1188	-1818	1016
30°	-1124	1337	43	-15	-239	-200	-1167	1332	-1363	1137
60°	-1041	1355	-30	5	-190	-213	-1071	1350	-1231	1142
90°	-1511	1217	-129	33	-124	-232	-1640	1250	-1635	982
-30°	-1825	1131	43	-15	-239	-200	-1782	1116	-2064	931
-60°	-1376	1224	-30	5	-190	-213	-1406	1229	-1589	1011
-90°	-122	1652	-129	33	-124	-232	-251	1685	-254	1420

A-4 LOAN REPAYMENT PLAN IN CASE ENTIRE AMOUNT OF TOTAL CONSTRUCTION COST PROCURED FROM GOVERNMENT FINANCING ORGAN AND APPLICABLE TARIFF RATES IN SUCH CASE

A-4 LOAN REPAYMENT PLAN IN CASE ENTIRE AMOUNT OF TOTAL CONSTRUCTION COST PROCURED FROM GOVERNMENT FINANCING ORGAN AND APPLICABLE TARIFF RATES IN SUCH CASE

1. PRECONDITIONS

Although rare, there can be a case when the entire amount of the total construction cost of a project is loaned by a government financing organ. Trial calculations will be made of the repayment plan and optimum electricity tariff rates in such a case. The preconditions for the calculations are as follows:

(a) The loan terms are interest rate of 4.5% and repayment period of 20 years. The repayment period includes a grace period consisting of the initial year of start-up.

(b) The electricity charge rates during the repayment period are to be such that the yearly electricity sales revenue will equal the total of the amount of loan repayment and the operation and maintenance cost (the minimum rate that a deficit will not be produced in the cash flow).

2. CALCULATION RESULTS

The results of calculations based on the conditions of the preceding paragraph are given in Table A-4-1 and Table A-4-2. In Table A-4-1, the total construction cost for each case and the corresponding loan repayment plan and operation and maintenance cost are indicated, and the minimum income required annually in order that a deficit will not be produced in the cash flow is calculated. The amount of loan repayment is made up of the proceeds and the depreciation cost. In Table A-4-2, the unit electricity sales prices per kWh calculated from the above proceeds, minimum income required and the energy sales are indicated. The conclusions below may be drawn from these tables.

3. CONCLUSIONS

3.1 Unit Energy Sales Price During Repayment Period

Comparing the unit energy sales prices of the first year (1984) and the final year (2002) of repayment of principal plus interest, the escalation rates during that period are calculated to be as shown below.

Item	Upper Estimate	Basic Estimate	Lower Estimate
Unit Energy Sales			
Price (US$/kWh)			
- 1984	0.0403	0.0387	0.0372
- 2002	0.0738	0.0622	0.0532
Annual Escalation			
Rate (%)			
- Compound interest av. escalation rate	3.4	2.7	2.0
- Single year escalation rate	1.7 - 5.0	1.6 - 3.8	1.3 - 2.9

The above unit energy sales prices for 1984 calculated based on the various costs taking into consideration commodity price escalation rates are, as indicated below, lower than the power supply cost of the alternative thermal at 1979 values.

Power Supply Cost of Alternative Thermal at 1979 Values

- kW cost US$109/kW
- kWh cost US$0.0264/kWh
- Power supply 15,640 kW
- Annual energy production 100,300 MWh

Therefore, the supply cost per kWh will be the following:

- Annual total cost

  (US$109 × 15,640) + (US$0.0264 × 100,300,000) = US$4,352,680

- Unit price per kWh

  US$4,352,680/100,300,000 kWh = US$0.0434/kWh

In effect, the unit energy sales prices in 1984 for the cases of upper, basic and lower estimates will correspond to only approximately 93%, 89% and 86% of the supply cost in 1979 of the alternative thermal, while the escalation rates in the unit energy sales rates required to obtain the necessary minimum income are well below the commodity price escalation rate in general. Therefore, it is considered to be quite possible for the electricity produced by this Project to be supplied at the above-mentioned unit energy sales prices.

3.2 Internal Rate of Return During Repayment Period

The internal rates of return of the enterprise during the first 20 years after start-up until repayment of the loan is completed may be calculated as shown below from the total construction costs (initial amount of working assets) of Tables A-4-1 and A-4-2 and the net operating profit.

Unit: 10^3US$

Item	Upper Estimate	Basic Estimate	Lower Estimate
(a) Initial amount of working assets	39,397	37,996	36,635
(b) Depreciation period	40 yr	40 yr	40 yr
(c) Annual av. depreciation amount	985	950	916
(d) 20-yr cumulative working assets balance	600,790	579,420	558,600
(e) 20-yr proceeds total	41,671	40,206	38,778
(f) Internal rate of return, (e)/(d)	6.94%	6.94%	6.94%

In effect, internal rates of return close to 7% can be secured in all cases. This would mean approximately 70% achievement of the target rate of 10%, but is approximately 88% achievement when compared with the traditional international standard of 8%. With this degree of rate of return secured, the target rate can be achieved in the latter 20-year period after completion of repayment with only very small adjustments in tariff rates so that the situation surely will not be unsatisfactory for the enterprise.

3.3 Applicable Tariff Rates After Completion of Repayment

Regarding electricity charges for the second-half 20-year period after completion of repayment, the tariff rates are to be adjusted so that the internal rate of return for the entire equipment depreciation period, or 40 years, will be at least 10%. In this case the annual average proceeds required for the latter 20 years will be as shown below.

Unit: 10^3US$

Item	Upper Estimate	Basic Estimate	Lower Estimate
(a) Initial amount of working assets	39,397	37,996	36,635
(b) Depreciation period	40 yr	40 yr	40 yr
(c) Annual av. depreciation amount	985	950	916
(d) 40-yr cumulative working assets balance	807,580	778,840	750,920
(e) Total proceeds required (d) x 10%	80,758	77,884	75,092
(f) Proceeds in 1st-half 20 years	41,671	40,206	38,778
(g) Proceeds in 2nd-half 20 years, (e)-(f)	39,087	37,678	36,314
(h) Annual av. proceeds of above	1,954	1,884	1,816

As for the annual operating revenue required, it must be the above annual average proceeds to which the operation and maintenance cost is added. Therefore,

. Operating Revenue Required in 21st Year

- Upper Estimate: $1,954 + 831 \times (1 + 0.09)^{20} = US\$6,611 \times 10^3$
- Basic Estimate: $1,884 + 801 \times (1 + 0.076)^{20} = US\$5,350 \times 10^3$
- Lower Estimate: $1,816 + 772 \times (1 + 0.062)^{20} = US\$4,387 \times 10^3$

. Operating Revenue Required in 40th Year

- Upper Estimate: $1,954 + 831 \times (1 + 0.09)^{39} = US\$25,900 \times 10^3$
- Basic Estimate: $1,884 + 801 \times (1 + 0.076)^{39} = US\$15,826 \times 10^3$
- Lower Estimate: $1,816 + 772 \times (1 + 0.062)^{39} = US\$9,878 \times 10^3$

Consequently, the unit energy sales prices per kWh of annual energy supplied in the 21st and 40th years will be the following:

. Unit Energy Sales Price in 21st Year

- Upper Estimate: 6,611/100,300 MWh = US$0.0660/kWh
- Basic Estimate: 5,350/100,300 MWh = US$0.0533/kWh
- Lower Estimate: 4,387/100,300 MWh = US$0.0437/kWh

. Unit Energy Sales Price in 40th Year

- Upper Estimate: 25,900/100,300 MWh = US$0.2582/kWh
- Basic Estimate: 15,826/100,300 MWh = US$0.1578/kWh
- Lower Estimate: 9,878/100,300 MWh = US$0.0985/kWh

On comparing the rates of the 21st year calculated according to the above with the rates of the 20th year, the final year of the repayment period, they are 11%, 14% and 18% lower for the cases of upper, basic and lower estimates, respectively. It is not realistic to lower the rates of the 21st year below that of the previous year simply to conform to an internal rate of return of 10%, and neither is it necessary to do so.

Upon comparing the rates of the 40th year with those of the 20th, there will be price escalations at compound interest rates of an annual 6.5% for the upper estimate, 4.8% for the basic estimate and 3.2% for the lower estimate. These escalation rates are fairly low compared with the rates for commodity prices in general and the records up to now of electricity charges.

Therefore, with regard to the tariff rates to be applied in the latter 20-year period, it will suffice to consider price raises, based on the rates of the final year of the repayment period, of about 6.5% annually in case of the upper estimate, about 4.8% annually in case of the basic estimate, and about 3.2% annually in case of the lower estimate, and with the above, it will be possible for an internal rate of return higher than 10% to be secured for this Project considering the entire length of the depreciation period.

Table A-4-1 Most Favorable Loan Repayment Plan and Minimum Revenue Required

Unit: 10^3US$

		Total Construction Cost			Loan Repayment Plan (A)			Operation and Maintenance Cost (B)			Minimum Revenue Required (C) = (A) + (B)			
No.	Year	Upper Estimate	Basic Estimate	Lower Estimate	Upper Estimate	Basic Estimate	Lower Estimate	Upper Estimate	Basic Estimate	Lower Estimate	Upper Estimate	Basic Estimate	Lower Estimate	
	1980	1,166	1,150	1,134	26	25	25							
	81	21,136	20,593	20,057	515	503	490							
	82	9,137	8,734	8,343	1,159	1,126	1,094							
1	1983	2,958	7,519	7,101	751	724	700	831	801	772	2,770	2,684	2,599	* (Note)
2	84				3,128	3,017	2,909	906	862	820	4,034	3,879	3,729	
3	85				"	"	"	987	927	871	4,115	3,944	3,780	
4	86				"	"	"	1,076	998	925	4,204	4,015	3,834	
5	87				"	"	"	1,173	1,074	982	4,301	4,091	3,891	
6	88				"	"	"	1,279	1,155	1,043	4,407	4,172	3,952	
7	89				"	"	"	1,394	1,243	1,108	4,522	4,260	4,017	
8	1990				"	"	"	1,519	1,338	1,176	4,647	4,355	4,085	
9	91				"	"	"	1,656	1,439	1,249	4,784	4,456	4,158	
10	92				"	"	"	1,805	1,549	1,327	4,933	4,566	4,236	
11	93				"	"	"	1,967	1,666	1,409	5,095	4,683	4,318	
12	94				"	"	"	2,144	1,793	1,496	5,272	4,810	4,405	
13	95				"	"	"	2,337	1,929	1,589	5,465	4,946	4,498	
14	96				"	"	"	2,548	2,076	1,687	5,676	5,093	4,596	
15	97				"	"	"	2,777	2,234	1,792	5,905	5,251	4,701	
16	98				"	"	"	3,027	2,403	1,903	6,155	5,420	4,812	
17	99				"	"	"	3,299	2,586	2,021	6,427	5,603	4,930	
18	2000				"	"	"	3,596	2,783	2,147	6,724	5,800	5,056	
19	1				"	"	"	3,920	2,995	2,280	7,048	6,012	5,189	
20	2				"	"	"	4,272	3,222	2,421	7,400	6,239	5,330	
Total		39,397	37,996	36,635				42,513	35,073	28,198	103,884	94,279	85,296	

Note: Minimum revenues required for 1983 calculated from unit energy sales prices in Table A-4-2 with said unit prices calculated inversely from unit energy sales prices for 1984.

Table A-4-2 Minimum Unit Energy Sales Price and Operating Balance

Unit: 10^3US$

No.	Year	Energy Sales (D) (MWh)	Minimum Unit Energy Sales Price (E) = (C)/(D)			Depreciation Cost (F)			Net Operating Profit (G) = (C) - (B) - (F)			
			Upper Estimate	Basic Estimate	Lower Estimate	Upper Estimate	Basic Estimate	Lower Estimate	Upper Estimate	Basic Estimate	Lower Estimate	
	1980											
	81											
	82											
1	1983	71,200	0.0389	0.0377	0.0365	985	950	916	954	933	917	*(Note)
2	84	100,300	0.0403	0.0387	0.0372	"	"	"	2,143	2,067	1,993	
3	85	"	0.0410	0.0393	0.0377	"	"	"	"	"	"	
4	86	"	0.0419	0.0404	0.0383	"	"	"	"	"	"	
5	87	"	0.0429	0.0408	0.0389	"	"	"	"	"	"	
6	88	"	0.0439	0.0416	0.0394	"	"	"	"	"	"	
7	89	"	0.0451	0.0425	0.0401	"	"	"	"	"	"	
8	1990	"	0.0463	0.0434	0.0407	"	"	"	"	"	"	
9	91	"	0.0477	0.0444	0.0415	"	"	"	"	"	"	
10	92	"	0.0492	0.0455	0.0422	"	"	"	"	"	"	
11	93	"	0.0508	0.0467	0.0431	"	"	"	"	"	"	
12	94	"	0.0526	0.0479	0.0439	"	"	"	"	"	"	
13	95	"	0.0545	0.0493	0.0449	"	"	"	"	"	"	
14	96	"	0.0566	0.0508	0.0458	"	"	"	"	"	"	
15	97	"	0.0589	0.0524	0.0469	"	"	"	"	"	"	
16	98	"	0.0614	0.0540	0.0480	"	"	"	"	"	"	
17	99	"	0.0641	0.0559	0.0492	"	"	"	"	"	"	
18	2000	"	0.0670	0.0578	0.0504	"	"	"	"	"	"	
19	1	"	0.0703	0.0599	0.0517	"	"	"	"	"	"	
20	2	"	0.0738	0.0622	0.0532	"	"	"	"	"	"	
Total		1,976,900	Annual Escalation Rate 3.4%	Annual Escalation Rate 2.7%	Annual Escalation Rate 2.0%				41,671	40,206	38,778	

Note: Unit energy sales prices in 1983 calculated inversely from unit energy sales prices in 1984 and annual escalation rates in unit prices.

A-5 BASIC DATA

A-5 BASIC DATA

Data Name	Publication
1. Hydrological and Meteorological Data	
1-1 Water Level-Discharge (Puente Sanchez Cerro Station)	DEPECHP
2. Geological Informations	
2-1 Informes Técnico de las Investigaciones Geognósticas Efectuadas para el Proyecto C.H. Curumuy (Marzo - 1977)	ELECTROPERU - INIE
2-2 Sinopsis Explicativa del Mapa Geológico del Perú. Bol. No. 28 (1977)	IGM
2-3 Mapa Geológico de la Zona de C.H. Poechos Curumuy	ENERGO PROJEKT
3. Data for Economic Evaluation	
3-1 Plan Nacional de Desarrollo para 1978 - 1979 (Volume I & II)	Sistema Nacional de Planificación
3-2 Banco Central de Reserva del Perú. Memoria 1977	Banco Central de Reserva del Peru
4. Data for Load Forcast	
4-1 Monthly Energy Production in Nov. 1978	E.E.P.S.A.
4-2 Annual Energy Production and Sales of Energy (1976 - 1978)	E.E.P.S.A.
4-3 Informe, Pronóstico de Demanda, Sistema Piura - Sullana	ELECTROPERU - INIE
5. Others	
5-1 Central Hidroeléctrica Curumuy y Poechos (Informe Intermedio)	ELECTROPERU
5-2 Informe del Perú, Piura	Promotora Editorial Latinoamericana
5-3 Anuario de Estadistica Eléctrica 1975	MEM
5-4 Almacenamiento y Derivación "CHIRA-PIURA" Diseño Final y Detallado. V-1 (Informe)	ENERGO PROJEKT
5-5 Mantaro I-Tercera Etapa, C.H. Restitución (Costo de Construcción)	ELECTROPERU - INIE

5-6	Proyecto "CHIRA-PIURA"	Ministerio de Agricultura y Alimentación
5-7	Plan de Electrificación Nacional 1978 - 1990	MEM
5-8	Anuarium '78 de la Construcción	Camara Peruana de la Construcción
5-9	Plan de Electrificación Nacional. Programa de Equipamiento e Inversiones del Sistema Interconectado Centro-Norte	MEM
5-10	Informe Intermedio del Proyecto C.H. Poechos, Curumuy	ELECTROPERU - INIE
5-11	Anteproyecto Instalación Grupo Termoeléctrico Werkspoor - 5490 kW y Electrificación Integral Pueblos Jovenes - Piura	OGEM PERUANA S.A.
5-12	Plan and Sections of Transmission Line Pole	ELECTROPERU - INIE
5-13	Poechos Power House, Plan, Profile and Section	ELECTROPERU - INIE
5-14	Curumuy Power House, Plan, Profile and Section	"
5-15	Single Line Diagram of Curumuy Power House	"
5-16	Switchyard of Curumuy Power House, Plan, Profile and Section	"
5-17	Sullana Substation, Plan, Profile and Section	"
5-18	General Layout of Transmission Line, Piura-Sullana System	EEPSA
5-19	General Layout of Transmission Line, Piura-Sullana System	ELECTROPERU - INIE
5-20	Impedance Map of Piura-Sullana System	"
5-21	Impedance Map of Piura-Sullana System (Caracteristics)	"
5-22	Transmission Line Protection System, 66 kV, Piura-Sullana	"
5-23	Plan, Ruta de Linea de Transmisión	"
5-24	Plan and Section of Transmission Line Pole	"
5-25	Mapa Fisico Político del Perú 1 : 2,000,000	IGM
5-26	Mapa Aerofotografía (Zona Piura) 1 : 100,000.	IGM