資料－6　ザンビア国の主要指標

Appendix-6　COUNTRY DATA

TABLE I—SELECTED INDICATORS

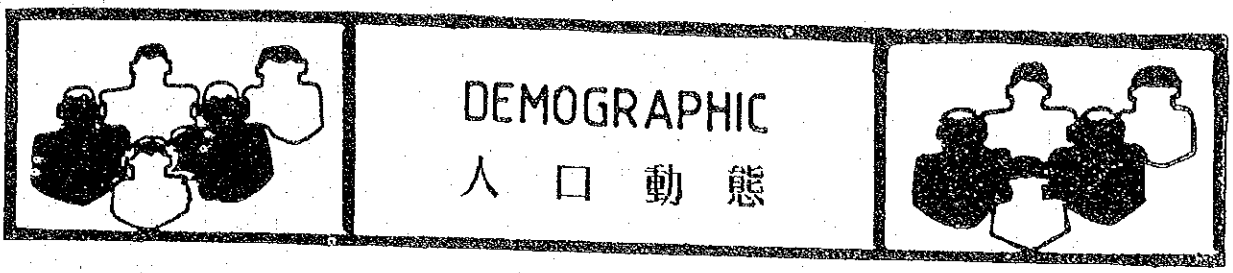
(ANNUAL AND QUARTERLY FIGURES)

	Unit	1977	1978	1979	1980	1981	1982	1983	1984	1984 Quarter III	1984 Quarter IV	1985 Quarter I
1 Population (Mid-year est)	million	5.20	5.36	5.52	5.68	5.87	6.05	6.22	6.42	...	...	..
2. Gross Domestic Product												
At current purchasers' values ...	K.million	1,986.4	2,250.7	2,660.4	3,063.6	3,485.4	3,595.3	4,181.2	4,733.3	...	...	...
At 1977 purchasers' values‡ ...	K'million	1,986.4	1,997.8	1,937.0	1,995.8	2,118·5	2,059.3	2,018.2	1,992.1	...	...	...
At 1977 purchaser's values ...	K'million	1,986.4	1,983.4	2,068.8	2,010.7	1,982.0	1,773.1	1,821.0	1,814.7	...	...	...
3. Per Capita Gross Domestic Product												
At current prices	Kwacha	382.0	419.9	482.0	539.4	596.8	594.3	672.2	737.3	..	..	..
At 1977 prices	Kwacha	382.0	372.0	350.9	351.4	362.8	340.4	324.6	310 3	..	..	..
At 1977 prices (Adjusted for terms of trade)	Kwacha	382.0	370.0	374.8	354.0	339.4	292.9	292.8	282..7	..	..	..
4. National Income												
At current market prices	K'million	1,607.4	1,809.8	2,124.3	2,495.9	3,004.1	2,870.3	3,508.3	3,910.3	...	...	...
At 1977 market prices (unadjusted)	K'million	1,607.4	1,616.9	1,575.5	1,671.2	1,856.6	1,778.2	1,773.2	1 770.1	...	...	...
At 1977 market Prices (adjusted)	K'million	1,607.4	1,512.5	1,707.3	1,686.1	1,719.7	1,492.0	1,595.5	1,592.7			
5. Per Capita National Income												
At current prices	Kwacha	309.1	337.6	384 8	439.4	514.4	474.4	564.0	609.1	...	...	..
At 1977 prices‡ ...	Kwacha	309.1	301.7	285.4	294.2	3 17.9	293.9	285.1	275.7	...	...	..
At 1970 prices	Kwacha	309.1	282.2	309.3	296.8	294.5	246.5	253.3	248.1	...	...	..
6. Gross National Product												
At current prices	K'million	1,898.3	2,109.4	2,431.8	2,835.0	3,387.5	3,276.1	3,935.0	4,358.0	.	..	..
At constant 1977 prices												
At constant 1977 prices (Unadjusted)	K'million	1,898.3	1,830.5	1,788.6	1,879.1	2 078.2	1,981.5	1,945.0	1,915.7	..	..	..
At constant 1977 prices (adjusted)	K'million	1,898.3	1,866.1	1,920.4	1,894.0	1,941 3	1,695.3	1,747.2	1,738.3	..	..	..
7. Copper production, exports, price												
Production	'000 tonnes	659.8	655.6	584·5	610.2	560.6	584.8	576.1	523.3	143.6	129.7	131.5
Exports	'000 tonnes	666.6	589.4	651·1	621.7	551.8	606.6	550.6	530.4	142.0	138.7	..
LME Cash and Settlement Price per ton	Kwacha	1,01.6	1,090	1,572	1,719	1,514	1,374	1,985	2,500	2,478	2,733	32.0
8. Index of Production												
Mineral Production	1973=100	94.2	95.4	86.1	89.2	82.0	86.0	84.4	77.0	83.3	75.2	78.8
Manufacturing	1973=100	98.5	102.6	96.2	99.2	104.9	100.1	94.5	94.9	99.6	93.7	107.8
Electricity	1973=100	265.0	240.7	248.4	280.7	293.8	323.5	308.5	293.5	299.9	275.4	294.3
9. External Trade												
Exports	K'million	708.0	656.8	1,090.0	1,023.3	936.5	950.5	1,047.5	1,188.1	332.2	316.3	..
Imports	K'million	530.0	492.6	593.7	876.7	924.4	930.0	893.3	1,107.9	313.6	316.9	..
10. Prices												
Index Numbers of Consumer Prices												
High Income	1975=100	136.8	152.6	169.8	189.4	209.1	236.6	278.6	336.8	342.0	359.3	390.3
Low Income	1975=100	142.3	165.6	181.6	202.9	231.3	260.2	311.2	373.5	378.2	399.5	449.7
Index Numbers of Wholesale Price												
Including Copper	1966=100	211.6	246.4	306.2	334.3	352.1	375.5	465.8	596.2	612.9	646.0	710.8
Excluding Copper	1966=100	278.9	333.7	398.6	439.2	487.5	541.9	653.3	830.6	861.4	897.0	967.7
11. Employment and Earnings												
Number of employees as on 31st December												
Zambian	'000	344	343	351	359	355	350	348	351	...	...	...
Non-Zambian	'000	26	23	23	20	19	17	16	14	...	...	...
Total	'000	370	367	374	379	373	368	364	365	...	...	...
Average annual earnings												
Zambian	Kwacha	1,566	1,742	1,657	2,301	2,392	2,556	2,647	..	...	..	...
Non-Zambian	Kwacha	7,096	6,897	6,122	8,715	8,111	8,258	8,071	..	...	..	...
12. Government Finance												
Receipts	K'million	638	686	856	1,174	1,220	1,191	1208	1,084	220	352	..
Payments	K'million	821	815	956	1,658	1,389	1,643	1337	..	329	..	..
13 Money Supply	K'million	418	420	551	555	599	727	827	872	929	872	859

Note: Figures on Employment and Earnings for 1981 to 1984 are for the Quarter ending June.
1980 popuration figure is from the 1980 Census.
‡unadjusted for changes in terms of trade.

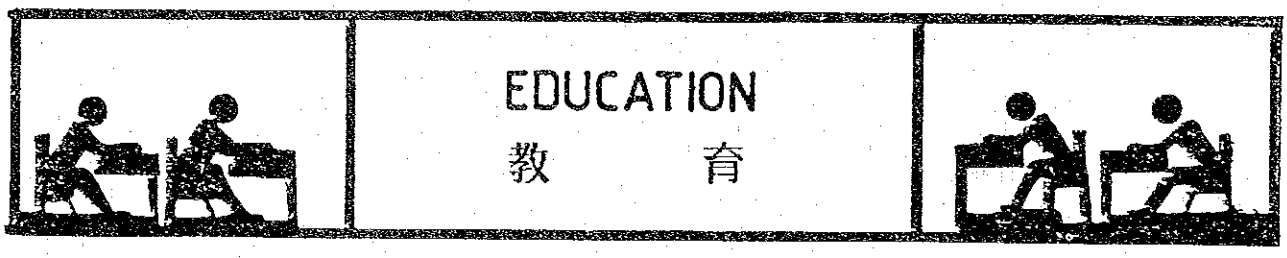
[Source: Monthly Digest of Statistics, August/September, 1985]

以下の資料は、表示してあるものを除き、Selected Socio-Economic Indicators,1984, Central Statistical Office, Zambia の抜粋である。



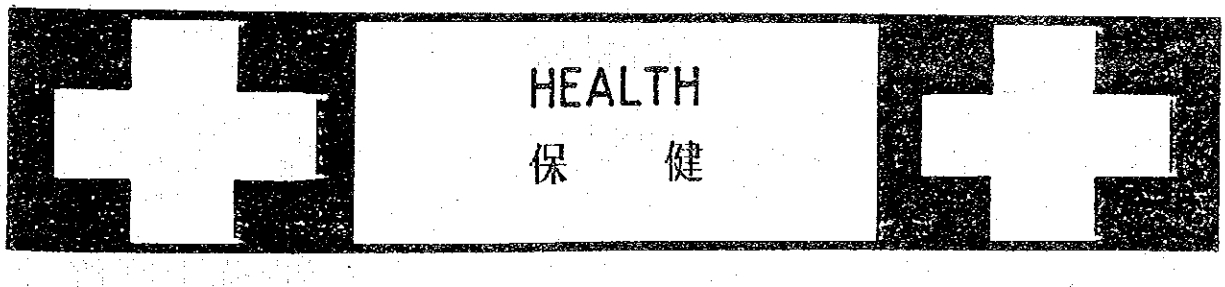
		1969	1980
1.1	Population enumerated (million)	4.06	5.68
1.2	Projected population (million)	1984	1989
		6.44	7.53
		1969	1979-84
1.3	Crude birth rate (per 1,000 population)	47.7	48
1.4	Crude death rate (per 1,000 population)	19.7	17
		1963-69	1969-80
1.5	Growth rate (%)	2.5	3.1
		1969	1980
1.6	Sex ratio (males per 100 females)	96.0	96.0
1.7	Total fertility rate (average number of children born to a woman)	6.9	-
1.8	Gross reproduction rate (average number of female births to a woman)	3.4	-
			1979-84
1.9	Life expectancy at birth, total	43.4	48.3
	males	41.8	46.7
	females	45.0	50.0
			1980
1.10	Infant mortality rate (per 1,000 live births)	141	-
1.11	Child population (0-14) (%)	46.3	46.3
1.12	Dependency ratio (per 100 population)	94.3	94.3
1.13	Child dependency ratio (per 100 population)	90.0	90.0
1.14	Population density (persons per sq. km)	5.4	7.5

			1980
1.15	Urban population (%)	29.4	43.0
1.16	Population in large urban areas (> 50,000 inhabitants) (%)	27.6	33.5
1.17	Rural population (%)	70.6	57.0
		1963-69	1969-80
1.18	Growth rate urban population (%)	8.9	6.7
1.19	Growth rate rural population (%)	0.5	1.1
		1969	1980
1.20	Average household size total	4.6	-
1.21	Female headed households (%)	23.8	-



			1969	1980
2.1	Population with no schooling (%)			
		Total	52	-
		Males	39	-
		Females	65	-
	Primary Schools		1971	1980
2.2	Number of primary school pupils ('000')		730	1,042
		% females	44.9	46.8
2.3	% of school age children (7-14) enrolled in primary schools			
		Total	79.4	83.7
		Males	86.8	88.3
		Females	71.9	79.0
2.4	% of 7 years old enrolled in Grade 1		N.A.	95.4

		1971	1980
2.5	Progression rate from Grade 4 to Grade 5 (%)	72	86
2.6	Progression rate from Grade 7 to Form I (%)	23	20
2.7	Pupil/teacher ratio in primary schools	49.6	49.2
	Secondary Schools		
2.8	Number of secondary school pupils ('000')	56	95
2.9	% females of total enrolment in secondary schools	33.0	35.1
2.10	% of population 15-19 enrolled in secondary schools	12.3	15.9
2.11	Progression rate from Form III to Form IV (%)	N.A.	49.1
2.12	Pupil/teacher ratio in secondary schools	21.7	22.0
	Teachers		
2.13	% trained teachers in primary schools	85.1	87.1
2.14	% trained teachers in secondary schools	83.3	95.5
2.15	% Zambian teachers in primary schools	94.1	98.7
2.16	% Zambian teachers in secondary schools	13.0	58.1



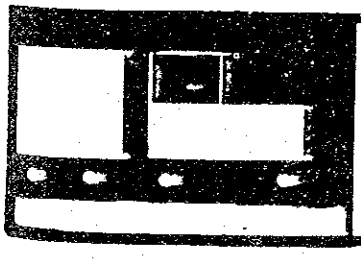
	Access to Health Facilities		1972	1980
3.1	Population within 12 km of a health unit	Total %	75	85
		Rural %	N.A.	73

		1972	1980
3.2	Population within 12 km of a health centre	N.A.	68
3.3	Population within 30 km of a hospital	N.A.	59
	Health Facilities		1981
3.4	Number of hospitals	76	81
3.5	Beds and cots in hospitals	12,870	15,326
3.6	Hospital beds per 1,000 population	2.9	2.6
3.7	Number of health centres/clinics	595	758
	% in rural areas	74	75
3.8	Beds and cots in health centres/ clinics	4,530	5,931
3.9	Total beds and cots per 1,000 population	3.9	3.6
	Rural	N.A.	1.7
	Urban	N.A.	5.8
	Health Personnel		
3.10	Number of doctors	N.A.	821
3.11	Doctors per 100,000 population	N.A.	14.0
3.12	Number of nurses	N.A.	5131
3.13	Nurses per 100,000 Population	N.A.	87.4
3.14	Number of health workers per 1,000 population	N.A.	1.4
	Nutrition		1967-72
3.15	Per Capita Calorie Consumption (recommended levels in brackets)		
	Urban		2,047 (2,060)
	Wage earners in small townships		1,955 (2,030)
	Rural subsistence farmers		1,357 (2,030)
	Wage earners in rural areas		1,720 (2,030)

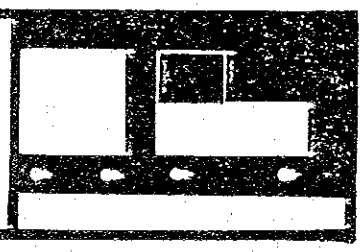
		1970-71
3.16	Percentage malnourished children (0-4 years)	
	below 80% weight-for-age standard	55
	below 90% weight-for-height standard	58

HOUSING AND ENVIRONMENT 住宅及び上下水道

		1969	1980
4.1	Average number of persons per room	2.6	-
4.2	% of dwellings with durable		
	roofs	27.2	-
	walls	46.9	-
4.3	% of dwellings with electricity	12.4	-
4.4	% of households using wood, coal or charcoal as cooking fuel	84.2	-
4.5	Water supply		
	Piped water (%)	27.6	-
	Well/borehole (%)	34.6	-
	River or stream (%)	32.3	-
	Other (%)	5.5	-
4.6	Water disposal method		
	Flush, aqua, pit, bucket (%)	50.1	-
	None (%)	49.9	-



INFRASTRUCTURE 社会基盤施設



		1977	1981
5.1	Total number of telephones ('000')	56	61
5.2	Telephones per 10,000 population	107	104
5.3	Total number of post offices/postal agencies	254	344

		1977	1981
5.4	Population per post office/postal agencies ('000')	20	17
5.5	Total number of vehicles ('000')	149	124
5.6	Number of vehicles per 10,000 population	286	211

		1978	1982
5.7	Road network ('000 km)		
	of which	36	37
	% bitumen	14.7	15.1
	% gravel	21.5	23.5

		1977	1981
5.8	Railway passenger - kilometres per capita	57	63

		1978	1981
5.9	Electricity production (mill. Kw)	7,883	9,793

		1975	1981	1982
6.1	Labour force ('000')	1,479	1,824	1,880
6.2	Number of persons employed by the formal sector ('000')	393	374	368
6.3	Formal sector employment as percent of total labour force	27	21	20

		1975	1979	1980
6.4	% females of total formal sector employment	6.3	7.7	7.6

		1975	1979	1980
6.5	Sectoral distribution of formal sector employment			
	agriculture (%)	9.2	9.7	9.6
	mining and quarrying (%)	16.5	16.2	16.2
	manufacturing (%)	11.3	12.8	13.2
	community, social and personal services (%)	24.8	28.4	29.0

		1977	1979	1980
6.6	Average annual earnings of Zambians employed in the formal sector (Kwacha) 2nd quarter	1,657	2,000	2,194
	Agriculture	647	878	995
	Mining and quarrying	2,344	2,636	2,935
	Manufacturing	1,624	1,890	2,082
	Personal services	1,660	2,016	2,145

		1978	1981	1982
	National Income			
7.1	Gross Domestic Product (GDP)			
	at current prices (K'million)	2,240	3,449	3,564
	at 1970 prices (K'million)	1,484	1,484	1,454
7.2	Per Capita GDP			
	at current prices (K)	418	588	589
	at 1970 prices (K)	277	253	240

		1978/79	1981/82
7.3	Growth rate GDP (%)	-7.7	-2.0

		1978	1981	1982
7.4	Sectoral contribution to GDP agricultural sector			
	K'million	169.2	180.0	159.0
	%	11.4	12.1	10.9

		1978	1981	1982
	mining and quarrying			
	K'million	494.1	433.3	433.4
	%	33.3	29.2	29.8
	manufacturing			
	K'million	159.6	180.0	173.0
	%	10.8	12.1	11.9
7.5	National Income			
	at current prices (K'million)	1,809	2,917	2,881
	at 1970 prices (K'million)	1,326	1,368	1,328
7.6	Per Capita National Income			
	at current prices (K)	338	497	477
	at 1970 prices (K)	248	233	219
7.7	Gross fixed capita formation			
	at current prices (K'million)	437	610	618
	at 1970 prices (K'million)	164	150	132

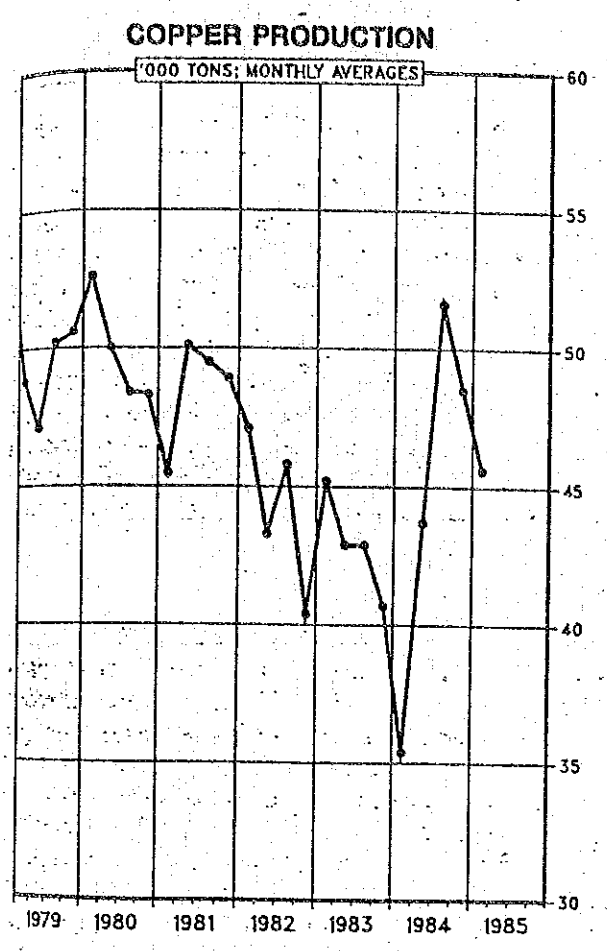
	Income Distribution	1974/75
7.8	Percentage of total income accruing to:	
	0-19% of the population	3
	20-39% of the population	6
	40-59% of the population	11
	Urban	
	0-19% of the population	6
	20-39% of the population	9
	40-59% of the population	12
	Rural	
	0-19% of the population	4
	20-39% of the population	8
	40-59% of the population	15

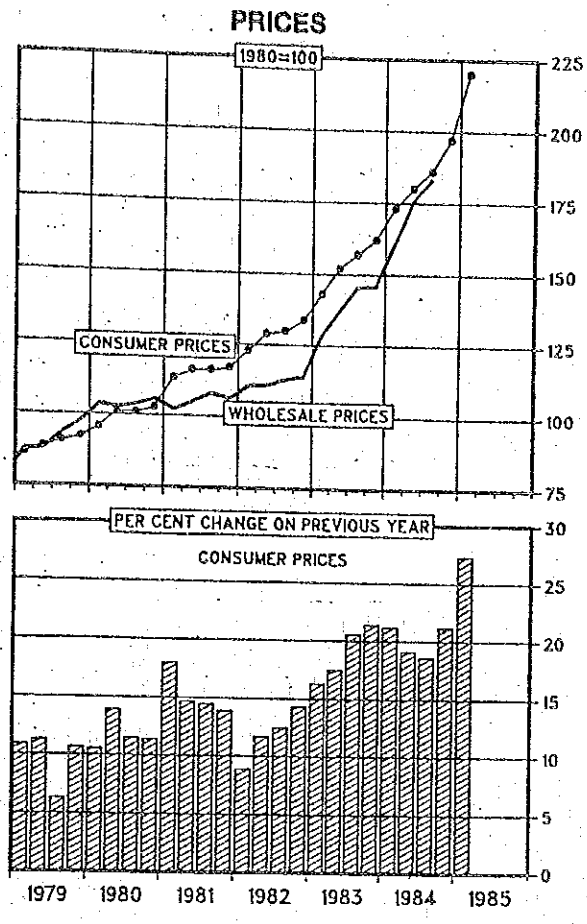
			1976
7.9	Average annual income per capita (K)	136	193
	Urban	255	354
	Squatter	170	238
	Low income	186	270
	High income	1,054	1,433
	Rural	74	

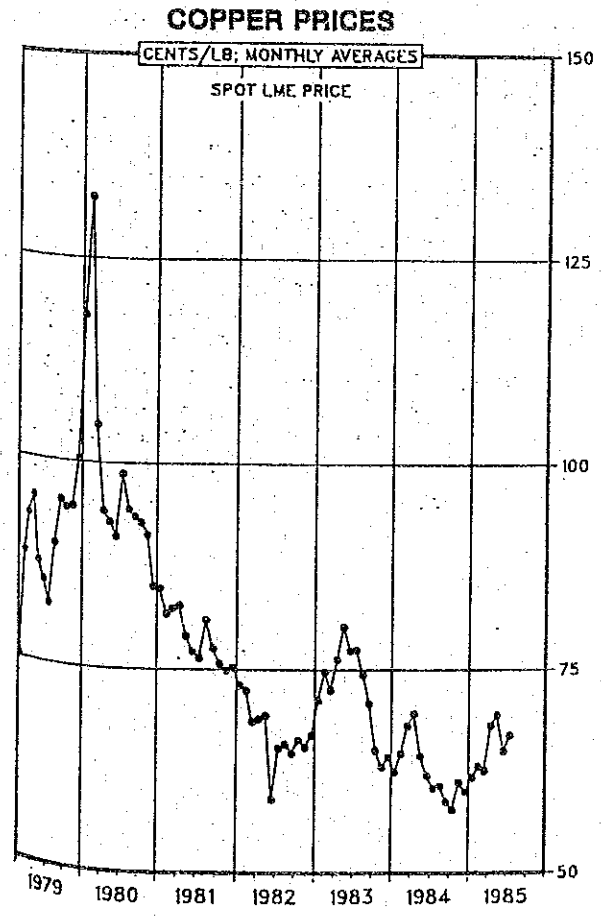
		1978	1981	1982
	Inflation			
7.10	Increase in the index of consumer prices (%)	15.8	13.6	12.6
7.11	Index of consumer prices (1975 = 100)	163.9	228.5	257.2
	Government Revenue and Expenditure			
7.12	Total Government revenue (K'million)	584.3	852.1	878.7
7.13	Total Government expenditure (K'million)	815.4	1,388.6	1,643.2
	current	647.1	1,230.5	1,323.0
	capital	168.3	158.1	320.2
7.14	% Government expenditure			
	health, total	6.5	5.6	7.2
	current	7.6	5.9	6.5
	capital	2.0	3.2	3.7
	education, total	13.6	11.0	13.0
	current	15.4	11.9	14.9
	capital	4.7	2.6	4.6
	Money and Banking			
7.15	International reserves (net) (K'million)	236.8	383.2	192.4
7.16	Currency in circulation (K'million)	154.8	224.2	242.7
7.17	Private deposits (Demand, Savings and Time Deposits)	567.3	843.1	1,159.5
7.18	Government deposits (with Bank of Zambia) (K'million)	7.5	-462.6	-944.4
7.19	Commercial bank loans and advances	301.6	699.8	747.7
	Consumption/Investments (Current Prices)			
7.20	Government final consumption (K'million)	575	1,054	1,072
7.21	Private final consumption (K'million)	1,203	2,166	2,254

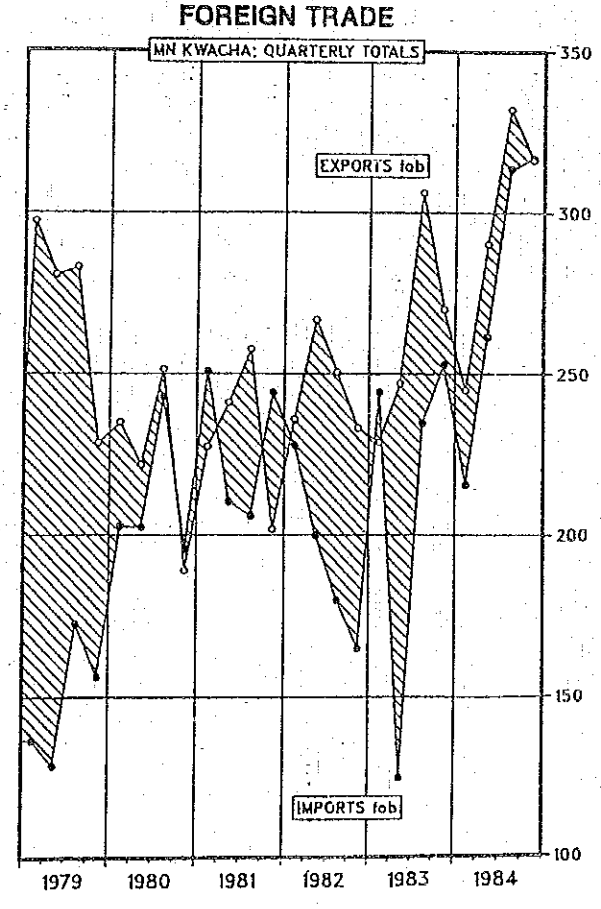
		1978	1981	1982
7.22	Gross domestic investment (K'Million)	537	673	603
7.23	Gross domestic savings (K'Million)	-18.5	-417.5	-480.8
7.24	Copper Production, Export, Price			
	Production ('000 tonnes)	655.6	560.6	614.9
	Exports ('000 tonnes)	589.2	551.8	603.5
	Price per ton (LME Cash and Settlement Price) (K)	1,572	1,514	1,374
7.25	Index of Production (1973 = 100)			
	Mineral production	95.4	82.0	86.0
	Manufacturing	102.6	104.9	100.1
	Electricity	240.7	293.8	323.5
	International Trade	1977	1980	1981
7.26	Value of imports (K'million)	530	877	924
	% machinery and equipment	38.7	34.5	34.0
	% electricity and mineral fuels	15.3	22.6	21.9
	% food	5.4	4.4	5.5
7.27	Total exports (K'million)	708.0	1,023.3	936.5
7.28	Balance of trade (export surplus) (K'million)	178	147	12
7.29	Direction of foreign trade			
	% imports from			
	EEC	22	38	-
	U.K.	23	23	-
	% exports to			
	EEC	39	51	-
	U.K.	16	14	-
	Japan	18	16	-
	U.S.A.	10	11	-

Economic Trends in Zambia [Source: Economic Review, 1985, EIU]

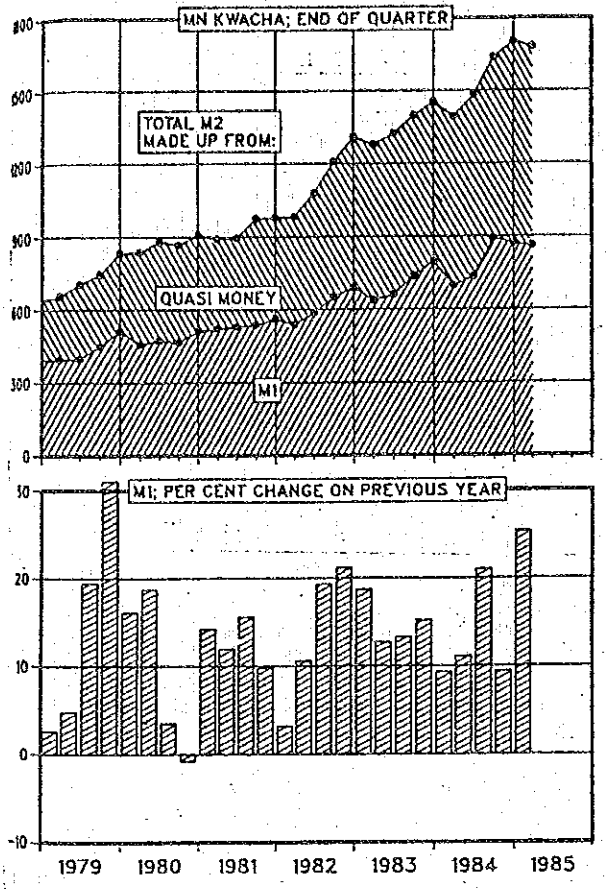




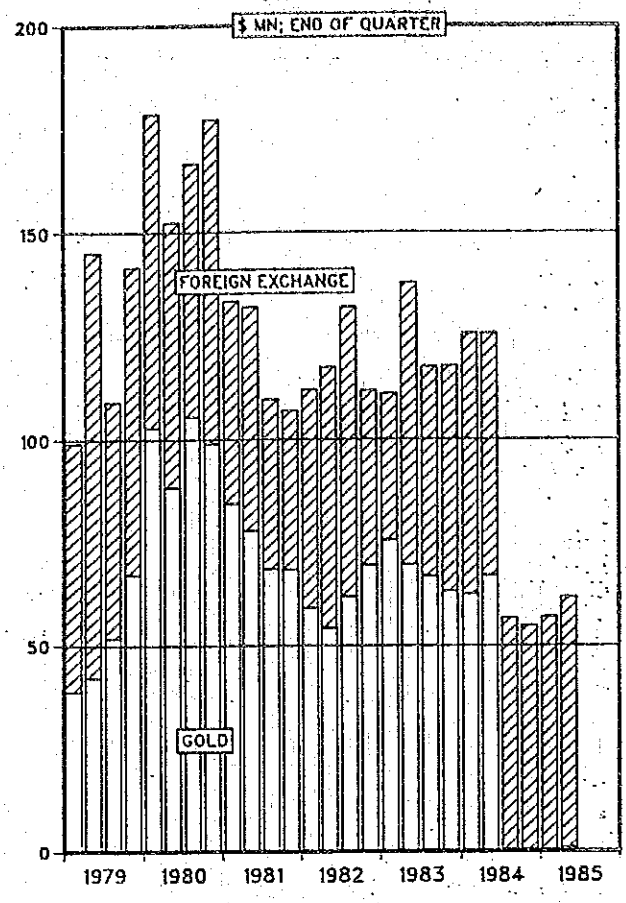




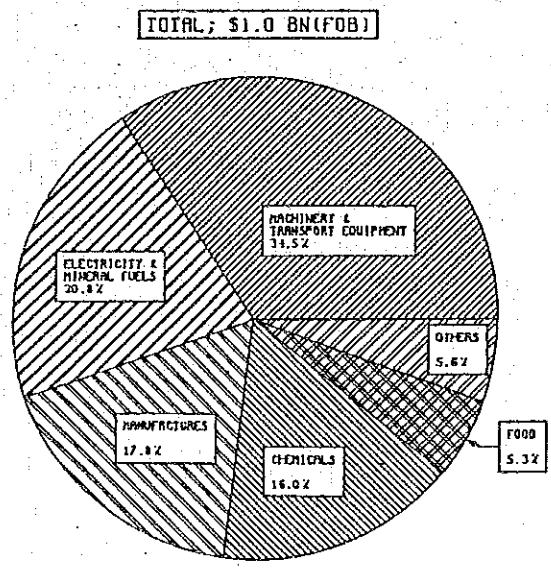
MONEY SUPPLY



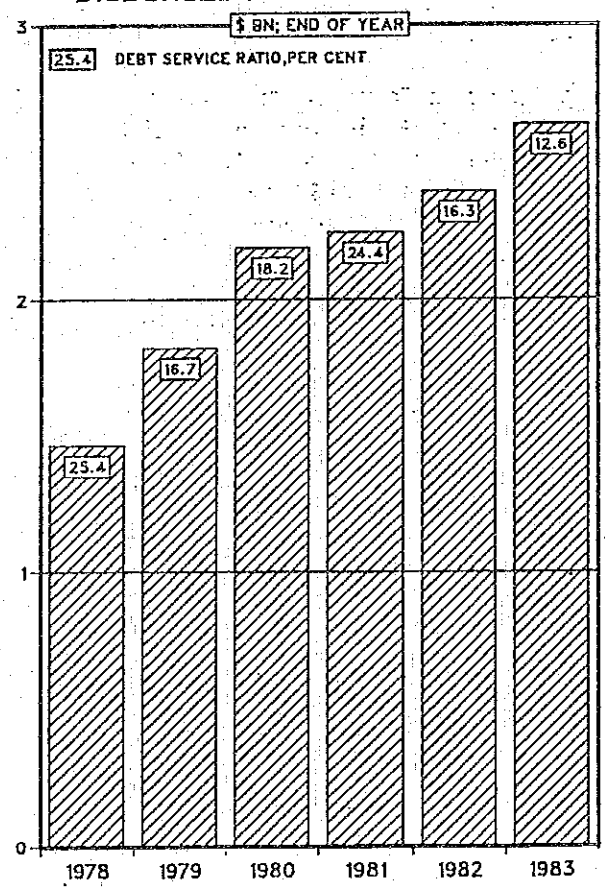
RESERVES



ZAMBIAN IMPORTS: 1982

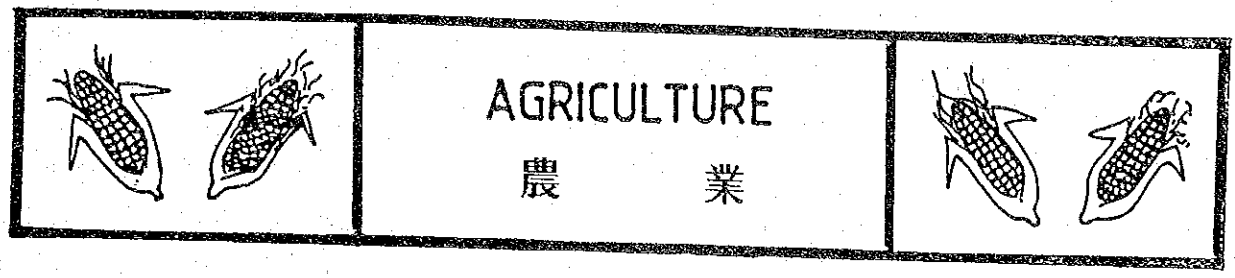


DISBURSED PUBLIC FOREIGN DEBT



[Source: Economic Review, 1985, EIU]

	Balance of Payments	1977	1980	1981
7.30	Overall balance of payments (K'million)	-224.3	-214.0	-341.4
7.31	Inflow of private capital (net) (K'million)	27.9	-67.7	91.7
7.32	Current account balance (K'million)	-208.1	-490.3	-656.7



		1975	1978
8.1	Arable land (million ha)	N.A.	42
8.2	Arable land per agricultural population (ha)	N.A.	13.8
8.3	Number of traditional households engaged in farming ('000')	614	626
8.4	Number of commercial farmers	1,530	1,580

		1975/76	1976/77	1977/78
8.5	Loans released to farmers by financial institutions (K'million)	41	51	63
	Credit per farmer (K'000)	2.2	2.7	2.4

		1976	1981	1982
8.6	Marketed production of selected crops			
	Sugarcane ('000 tonnes)	768	893	1,010
	Maize ('000 tonnes)	559	693	510
	Wheat ('000 tonnes)	0.9	11	13
	Rice ('000 tonnes)	1.0	2.7	2.9
	Sunflower ('000 tonnes)	8.2	19	21
	Seed cotton ('000 tonnes)	2.6	17	13
	Cotton lint ('000 tonnes)	0.9	6.3	4.9
	Tobacco ('000 tonnes)	7.0	3.0	2.6

		1975	1980	1981
8.7	Percentage contribution of traditional farmers in marketed maize	60	60	46
8.8	Imports			
	of maize ('000 tonnes)	0.04	43	81
	of wheat ('000 tonnes)	157	35	79
	of rice ('000 tonnes)	3.9	4.6	2.4
8.9	Production of meat and milk (commercial sector)			
	Cattle ('000 heads)	72	92	100
	Pigs ('000 heads)	55	48	38
	Poultry ('000 tonnes)	11	18	12
	Milk ('million litres)	12	9	11

		1975	1978	1979
8.10	Production of major fisheries ('000 tonnes)	41	43	50

		1975	1981	1982
8.11	Percentage share of commercial and subsistence agricultural sector to GDP			
	Commercial sector			
	at current prices	4.0	6.0	5.3
	at 1970 prices	3.9	4.8	4.1
	Subsistence sector			
	at current prices	9.1	9.8	8.3
	at 1970 prices	7.0	7.3	6.9

WATER ANALYSES OF UNTREATED WATER FROM KAFUE RIVER AT IOLANDA INTAKE (1974 - 1976)

資料7 水質データ
Appendix-7 DATA ON WATER QUALITY

characteristic	9-1-74	15-2-74	20-3-74	17-4-74	15-5-74	12-6-74	18-9-74	9-10-74	6-11-74	4-12-74	8-1-75	12-2-75	6-3-75	7-5-75	11-6-75	10-9-75	8-10-75	5-11-75	5-12-75	11-2-76
Appearance	Dirty Brown	Greenish Brown	Greenish Brown	Brownish Green	Greenish	Greenish	Brownish	Greenish	Greenish	Greenish Brown	Brownish	Brownish	Brownish	Greenish	Greenish	Brownish	Greenish	Brownish	Greenish	
Odour	Musty	Musty	Musty	Musty	Musty	Musty	Musty	Musty	Musty	Musty	Musty	Earthy	Musty	Earthy	Earthy	Earthy	Earthy	Earthy	Earthy	Earthy
Turbidity	8	3	7	4	2	2	3	2.4	4	6	5	4	6	4	8	3	3	3	4	6
Color °Hazen	30	50	40	40	20	8	15	15	15	35	20	35	25	15	15	10	12	10	10	25
PH	7.4	7.2	7.2	7.2	7.0	7.1	7.5	7.5	7.6	7.7	-	7.4	7.3	7.6	7.3	7.7	7.8	7.7	7.7	7.7
Total Dissolved Solids	93	153	141	136	99	122	115	167	191	224	194	87	152	136	129	166	130	133	152	160
Electrical Conductivity (micro mhos/cm)	240	160	150	135	110	110	190	200	210	240	230	180	170	110	110	160	190	220	240	220
Alkalinity as $CaCO_3$	116	74	80	82	74	80	106	120	130	120	94	86	88	80	80	100	105	124	132	112
Hardness as $CaCO_3$																				
Carbonate			80		64	80	106	104	0	120					0					
Non-Carbonate	8	6		6			0	0	130	10	6	0	8	0		0	-	-	0	10
Total	124	80	80	88	64	80	104	104	120	130	100	80	80	64	64	92	108	110	130	122
Calcium	106	64	64	68	64	65	94	100	120	126	80	64	60	60	52	86	90	104	88	89
Magnesium	18	16	16	20	0	15	10	4	0	4	20	16	20	-	12	6	18	6	42	33
Sodium Na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potassium K	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloride Cl	12	4	6	2	4	4	4	4	6	4	16	6	6	6	4	4	4	6	8	6
Sulphate SO_4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate N	0.06	0.08	0.01	0.10	0.06	0.08	0.1	0.08	0.10	0.08	0.08	0.14	0.10	0.06	0.06	0.01	0.02	0.04	0.03	0.05
Nitrite N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	0
Free Ammonia N	0.44	0.18	0.02	0.03	0.10	0.03	0.30	0.24	0.02	0.20	0.08	0.28	0.28	0.04	0.02	0.50	0.54	0.64	0.20	0.76
Albuminoid Ammonia N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxygen absorbed	35	1.6	1.5	5.1	3.7	2.9	6.8	9.0	3.9	5.4	4.1	4.1	2.2	2.5	4.0	4.6	2.8	3.6	4.0	4.0
Silica SiO_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phosphate PO_4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese Mn Total	0	0	-	0	-	0	0	0	-	0	-	-	0	-	-	-	-	-	-	-
Free Chlorine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Suspended Solids	10	-	-	-	-	-	-	-	3.0	-	-	5	-	-	-	-	-	-	-	-
BOD (5 days)	20	5.6	5.6	1.3	0.5	0.8	1.25	0.7	1.3	1.7	-	1.5	1.7	0.9	0.3	2.0	0.9	0.8	1.7	1.8
Temperature	26	26	27	28	25	23	24	27	27	27	28	25	25	26	26	26	27	30	28	28.5
Dissolved Oxygen	2.8	1.8	0.1	1.1	1.0	1.5	2.7	2.7	2.0	2.7	2.6	1.5	1.5	1.2	2.5	6.5	7.7	7.0	10.0	7.3
Saturation	40	25.7	1.4	15.7	14.5	21.5	38.5	38.5	28.9	39.1	37.7	21.7	21.7	17.1	35.7	92.8	110.0	101.4	146.0	105.8

in mg/l except where shown otherwise.

[Source: Zambia Water Wastage Study, 1977]

WATER ANALYSES OF TREATED WATER
AT OUTLET OF STEWART PARK SERVICE RESERVOIR
(1974 - 1976)

Characteristic	10-1-74	17-2-74	14-3-74	17-4-74	16-5-74	13-6-74	17-9-74	10-10-74	7-11-74	5-12-74	9-1-75	13-2-75	5-3-75	13-5-75	12-6-75	11-9-75	10-10-75	6-11-75	8-12-75	12-2-76
Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Bright	Clear	Greenish	Clear	Clear	Clear	Clear	Bright.					
Odour	None	None	None	None	None	None	Chlorinous	Chlorinous	None		None			None	None	None				None
Turbidity	Clear	Clear	1.0	1	0.0	Clear	None	Clear	Clear	1.2	Nil	Nil	None	Nil	Clear	Clear	Clear	Clear	Clear	Clear
Color °Hazen	-5	-5	-5	-5	-5	-5	-5	-5	-5	5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
PH	7.0	6.9	7.1	7.0	7.0	7.0	6.6	6.6	7.1	7.2		6.9	6.9	7.0	6.8	7.0	7.2	7.0	7.5	7.5
Total Dissolved Solids	124	188	191	111	102	124	149	189	215	348	244	123	165	117	134	128	106	161	220	124
Electrical Conductivity (micro mhos/cm)	280	180	180	160	140	120	230	240	250	260	260	200	185	175	120	180	200	230	250	240
Alkalinity as $CaCO_3$	84	50	66	68	70	80	48	60	114	120	100	62	70	62	54	70	92	94	114	110
Hardness as $CaCO_3$																				
Carbonate			66		70	76	48	60	114						16					
Non-Carbonate	50	46	40	28	10	4	64	60	28	20	10	48	14	14		26	8	26	22	10
Total	134	96	106	96	80	76	112	120	142	140	110	110	84	76	70	96	100	120	136	120
Calcium	118	80	76	78	70	64	84	106	104	90	88	100	60	64	60	82	88	90	92	84
Magnesium	16	16	30	18	10	12	28	14	38	50	22	10	24	12	10	14	12	30	44	36
Sokium Na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potassium K	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloride Cl	16	16	8.0	6.0	6	6	40	36	8	6	12	4	8.0	4	6	6	8	10	10	15.9
Sulphate SO_4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate N	0.12	0.04	0.0	0.01	0.00	0.0	0.08	0.05	0.08	0.14	0.09	0.1	0.06	0.04	0.04	0.01	0.04	0.04	0.02	0.05
Nitrite N	0.00	0.00	0.0	0.00		0.0	0.0	0.0	0.0	0.0	0.0	0.0	Nil	0.0	-		0.0	Nil		0.0
Free Ammonia N	0.08	0.02	0.01	0.01	0.02	0.0	0.06	0.01	0.04	0.2	0.56	0.31	0.02	0.02	0.91	0.1	0.04	0.52	.04	0.14
Aluminoid Ammonia N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxygen Absorbed (4 Hrs, 27°C)	1.0	1.5	0.75	2.2	1.2	1.3	0.25	0.15	2.0	1.4	1.7	1.4	1.9	3.5	0.8	0.7	1.8	1.5	1.2	2.4
Silica SiO_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phosphate PO_4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iron Fe Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese Mn Total	0.00	-	-	0.00	-	-	-	0,0	-	-	-	-	-	-	-	-	-	-	-	-
Free Chlorine	Nil	Trace	Trace	Trace	Trace	Trace	0.7	1.2	Trace	Nil	Trace	Nil	Trace	Nil	Nil	Trace	Nil	Nil	Trace	Nil

Units in mg/l except where shown otherwise.

BACTERIOLOGICAL ANALYSIS

	SOURCE	DATE SAMPLED	COLIFORM ORGANISMS/100ML	95% CONFIDENCE LIMIT		CONFIRMED E. COLI	TOTAL BACTERIAL COUNT	REMARKS
				LOWER LIMIT	UPPER LIMIT			
1	CHELSTON	24/12/85	3	< 0.5	9	+	-	UNSATISFACTORY
2	NORTHMEAD	24/12/85	1	< 0.5	4	+	-	UNSATISFACTORY
3	KALAMBO ROAD WORKSHOP	24/12/85	Nil	-	-	-	-	SATISFACTORY
4	CHUNGA	24/12/85	Nil	-	-	-	-	SATISFACTORY
5	CHAWAMA	24/12/85	Nil	-	-	-	-	SATISFACTORY
6	WATER DISTRIBUTION RESERVOIR	24/12/85	Nil	-	-	-	-	"
7	KAFUE TREATMENT PLANT	27/12/85	Nil	-	-	-	-	"
8	CHILANGA PUMPING STATION	27/12/85	6	1	15	+	+	UNSATISFACTORY

BACTERIOLOGICAL ANALYSIS

	SOURCE	DATE SAMPLED	COLIFORM ORGANISMS/100ML	95% CONFIDENCE LIMIT		CONFIRMED E COLi	TOTAL BACTERIAL COUNT	REMARKS
				LOWER LIMIT	UPPER LIMIT			
1.	Intercontinental	2/01/86	18+	5	55	+		Unsatisfactory
2.	Chelston	2/01/86	18+	5	55	+		Unsatisfactory possible source reservoir
3.	Northmead	2/01/86	18+	5	55	+		Unsatisfactory
4.	Matero Police	2/01/86	6	1	15	+		Unsatisfactory
5.	Kalambo Road Workshop	2/01/86	Nil	0	0	-		Satisfactory
6.	Woodlands	2/01/86	Nil	0	0	-		Satisfactory
7.	Rhodes Park	2/01/86	Nil	0	0	-		Satisfactory
8.	Chilanga Pumping Station	4/01/86	9	2	21	+		Unsatisfactory
9.	Kafue Laboratory	4/01/86	2	< 0.5	6	-		Satisfactory

BACTERIOLOGICAL ANALYSIS

SOURCE	DATE SAMPLED	COLIFORM ORGANISM/100ML	95% CONFIDENCE LIMIT		CONFIRMED E. COLi	TOTAL BACTERIAL COUNT	REMARKS
			LOWER LIMITS	UPPER LIMITS			
CIVIC CENTRE	12/02/86	Nil	0	0	-	NO	Satisfactory
RIDGEWAY (OUTSIDE TAP)	12/02/86	3	0.5	9	+	2	Unsatisfactory
RIDGEWAY (INSIDE TAP)	12/02/86	18+	5	55	+	2	Unsatisfactory Gross pollution
NORTHMEAD PRIMARY SCHOOL	12/02/86	Nil	0	0	-	0	Satisfactory
MATERO POLICE STATION	12/02/86	"	0	0	-	0	"
LUMUMBA ROAD RESERVOIR	12/02/86	Nil	0	0	-	0	"
CHAWAMA RESERVOIR	12/02/86	"	0	0	-	0	"

BACTERIOLOGICAL ANALYSIS

SOURCE	DATE SAMPLED	COLIFORM ORGANISM / 100ML	99% CONFIDENCE LIMIT		CONFIRMED E. COLi	TOTAL BACTERIAL COUNT	REMARKS
			LOWER LIMITS	UPPER LIMITS			
CIVIC CENTRE	25/02/86	0	-	-	-	ND	Satisfactory
WATER DISTRIBUTION	"	0	-	-	-	ND	Satisfactory
STUART PARK	"	0	-	-	-	ND	Satisfactory
KALINDALINGA	"	18+	3	55	+	ND	Unsatisfactory
CHELSTON	"	3	0.5	9	-	ND	Unsatisfactory
LUMUMBA ROAD	"	6	1	15	+	ND	Unsatisfactory
CHAWAMA	"	9	2	21	-	ND	Unsatisfactory
CHILENJE	"	0	-	-	-	ND	Satisfactory

BACTERIOLOGICAL ANALYSIS

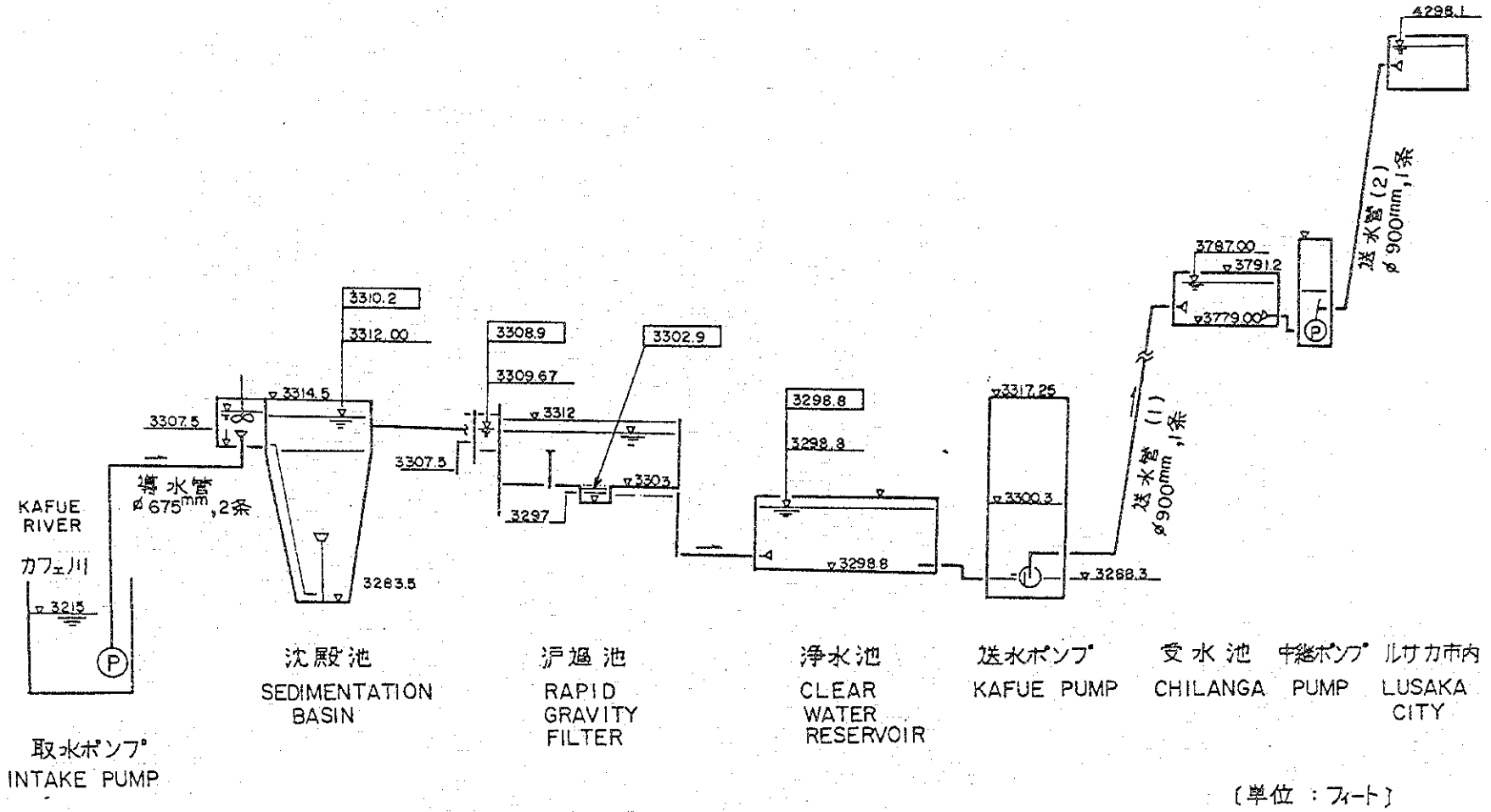
SOURCE	DATE SAMPLED	COLIFORM ORGANISM/100ML	95% CONFIDENCE LIMIT		CONFIRMED E. COLi	TOTAL BACTERIAL COUNT	REMARKS
			LOWER LIMITS	UPPER LIMITS			
CIVIC CENTRE	6/03/86	0	-	-	-	NO	Satisfactory
DISTRIBUTION	"	0	-	-	-	NO	Satisfactory
WOODLANDS	"	16	4	40	+	NO	Unsatisfactory
KALINGALINGA	"	18+	5	56	+	NO	Unsatisfactory
CHELSTON	"	16	4	40	+	NO	Unsatisfactory
CHUNGA	"	6	1	13	-	NO	Unsatisfactory
MATERO POLICE STATION	"	3	< 0.5	9	-	NO	Unsatisfactory
LUSAKA ROAD	"	0	-	-	-	NO	Satisfactory
CHAWAMA	"	4	< 0.5	11	-	NO	Unsatisfactory
CHILENGA PUMPING STATION	7/3/86	3	< 0.5	9	-	NO	Unsatisfactory

Appendix 8 Hydraulic Calculation of Kafue Treatment Plant

Hydraulic analysis is carried out in order to check whether 110,000 m3/day of water can flow through the existing water treatment plant without any hydraulic problem. Results of the analysis presented in Table 8.2 and Fig. 8.1 show a satisfactory allowance of water table (1.8 ft.) in the receiving well and that of some 7 ft. for the filter run.

Table 8.2. Results of Hydraulic Analysis in the Plant

Items	Water Level in Original Work (feet)	Water Level, etc. at the Flow of 110,000cmd		Allowance (feet)	Remarks
		Head Loss (feet)	Water Level (feet)		
Clear Water Reservoir	3,298.8	---	3,298.8	0.0	
Connecting Pipe (Clear Water Reservoir and Filter)		4.07	---	---	
Outlet of Filter	3,303.0	---	3,302.9	0.1	3298.9+4.07 = 3302.9
Filter		6.77	---	---	Head loss due to filtration is 5.8 feet
Inlet of Filter	3,309.67	---	3,309.67	---	
Connecting Conduit (Filter and Sedimentation Basin)		0.23	---	---	
Sedimentation Basin	3,312.0	---	3,310.2	1.8	
Connecting Conduit (Sedimentation Basin and Receiving Well)		0.22	---	---	
Receiving Well	3,314.5	---	3,312.22	2.3	



〔単位 ：フィート〕
〔UNIT : FEET〕
注）□ 内数値は
110,000㎥/日 時

図 8.1 カフェ系水位高低図(本計画)

Fig 8.1 Water Table of Kafue System (This Project)

(1) Loss between Clear Water Reservoir and Outlet of Filter $H_1 = h_1 + h_2 + h_3 + h_4$

ϕ 900 mm , l = 460ft. = 140 m

$Q = 110{,}000 m^3/day = 1.2731\ m^3/sec$

$$V = Q/A = 1.2731 / \frac{\pi}{4} (0.9)^2 = 2.0\ m/sec$$

① Inlet $h_1 = f_e \dfrac{V^2}{2g} = 0.5 \times \dfrac{(2.0)^2}{2 \times 9.8} = 0.10\ (m)$

② Outlet $h_2 = f_o \dfrac{V^2}{2g} = 1.0 \times \dfrac{(2.0)^2}{2 \times 9.8} = 0.20\ (m)$

③ Bend $h3 = f_{b1} f_{b2} \dfrac{V^2}{2g}$

45° ～ 2 Nos. 90° ～ 2Nos. $f_{b1} f_{b2}$: 45° bend 0.15, 90° bend 0.20

$$h_3 = (0.15 \times 2 + 0.20 \times 2) \frac{(2.0)^2}{2 \times 9.8} = 0.14(m)$$

④ Friction $h_4 = 10.294 n^2 D^{16/3} Q^2 L$ (Manning Formula)

$n = 0.014$ $D = 0.9$ $Q = 1.2731$ $L = 140m$

$h_4 = 0.80m$

⑤ Total

$H = 0.10 + 0.20 + 0.14 + 0.80$

$= 1.24\ m$

$= 4.07\ ft.$

(2) Loss in the Filter

$$H_2 = h_1 + h_2 + h_3 + h_4 + h_5 + h_6$$

$Q = 110{,}000 m^3/day \div 20$ filter $= 5{,}500 m^3/day = 0.0637\ m^3/sec/filter$

① Inlet (h_1)

$$V = 0.0637 \div 0.14 = 0.455\ m/sec$$

$$h_1 = (0.5 + 1.0)\frac{(0.455)^2}{2g} = 0.02m$$

Where, 0.5:Inlet, 1.0:Outlet

② Sand (h_2)

Loss in clear sand (Fair-Hatch formula)

$$h_2' = 0.178\ L \cdot \frac{\upsilon}{g} \cdot \frac{\alpha}{\beta} \cdot \frac{1}{\xi^4} \cdot \frac{24\mu}{\rho} \cdot \Sigma \frac{P_1}{D_1^2}$$

L : Thickness 0.6m υ : velocity m/sec, α / β : coefficient 5.5

ξ : Porous ratio 0.35 μ : Viscosity 10^{-3}kg/m・sec

ρ : Specific gravity 10^3 kg/m^3 D_1 : Diameter m

P_1 : Ratio of D_1

Where $\Sigma \frac{P_1}{D_1^2} = 1.5 \times 10^6$

$$h_2' = 0.178 \times 0.6 \times \frac{120}{86{,}400} \times \frac{1}{9.8} \times 5.5 \times \frac{1}{0.35^4} \times \frac{24 \times 10^{-3}}{10^3}$$

$$\times 1.5 \times 10^6$$

$$= 0.2m$$

Allowance of 1.56m is assumed.

$$h_2 = 0.2 + 1.56 = 1.76m$$

③ Gravel (h_3) $h_3 = 0.1m$

④ Collection (h_4) $h_4 = \frac{1}{2g} \frac{100}{0.6} \times \left(\frac{120}{86{,}400}\right)^2 = 0.003m$

⑤ Outlet (h_5) $\phi 375$, $V = 0.0637/(0.375^2 \frac{\pi}{4}) = 0.577$m/sec

$$h_5 = (0.5 + 1.0) \times \frac{(0.577)^2}{2g} = 0.03\text{m}$$

Where 0.5: Inlet, 1.0: Outlet

⑥ Loss of venturi, valve etc.

$h_6 = 0.14$m

⑦ Total

$H_2 = 0.02 + 1.76 + 0.1 + 0.01 + 0.03 + 0.14$

$= 2.06$m

$= 6.77$ ft.

(3) Loss between filter and sedimentation basin

Open channel (Width 3ft. = 0.91m , Depth 2.17ft. = 0.66m , l = 490ft.= 150m)

$H_3 = (N^2 \times V^2 \times L) \div (R^{4/3})$

$= (0.015^2 \times 0.71^2 \times 150) \div (0.337^{4/3})$

$= 0.07$ m

$= 0.23$ ft.

Where,

N : Roughness (concrete 0.015)

V : Velocity (1.2731 ÷ 3) ÷ (0.66 X 0.91) = 0.71

R : Hydraulic radius (A/S = 0.66 X 0.91 ÷ (0.66 X 2 + 0.91) = 0.337)

S : Wetted perimeter (= 0.66 X 2 + 0.91 = 1.78)

A : Sectional area (= 0.66 X 0.91 = 0.60)

(4) Loss between sedimentation basin and receiving well

Open channel (Width 3ft. = 0.91m , Depth 2.17ft. = 0.66m , l = 330ft.= 100m)

$H_4 = (N^2 \times V^2 \times L) \div (R^{4/3})$

$= (0.015^2 \times 0.71^2 \times 100) \div (0.337^{4/3})$

$= 0.068$ m

$= 0.22$ ft.

Appendix – 9 Calculation for Drain Trough of Filter

(1) Depth of Trough

$$H = \frac{Q}{1.838B}^{2/3}$$

$$= \frac{0.52}{1.838 \times 4.5 \times 5 \times 2}^{2/3}$$

$$= 0.034 \text{ m}$$

Where,

Q : Rate of discharge $47.25 \text{ m}^2 \times 0.66 \text{ m/min}$

$= 31.185 \text{ m}^3/\text{min}$

$= 0.52 \text{ m}^3/\text{sec}$

B : Length of trough : 4.5 m × 5 Nos./filter × 2

H : H (m)

(2) Dimension of Trough

Section of Trough ^{W} 0.35 × ^{D} 0.4

Number of Trough 5 Nos./filter

Rate of dischrge per trough

$$Qo = \frac{0.52}{5} = 0.104 \text{ m}^2/\text{sec}$$

Critical depth h_{co}

$$h_{co} = \left(\frac{\alpha Q_o^{\ 2}}{g B^2} \right)^{1/3}$$

$$\alpha = 1.1$$

$$Q_o = 0.104 \text{ m}^3/\text{sec}$$

$$B = 0.35\text{m}$$

$$h_{co} = \left(\frac{1.1 \times (0.104)^2}{9.8 \times (0.365)^2} \right)^{1/3}$$

$$= 0.215 \text{ m}$$

When discharge is free, depth in the upstream is,

$$h_o = \sqrt{3}\ h_{co}$$

$$h_o = \sqrt{3} \times 0.215$$

$$= 0.372 \text{ m} < 0.40 \text{ m}$$

Then, trough section of 350 ^{W} × 400 ^{H} is OK.

APPENDIX 10 CALCULATION FOR SPECIFICATION OF TRANSFER PUMP

The specification of transfer pump shall be determined by using the loss coefficient of existing pipeline.

1. Loss coefficient of existing pipeline

Loss coefficient of existing pipeline calculated by using Hazen-Williams Formula and existing pipeline profile drawing is shown in clause a.

In Table a., loss coefficient C value will be 120-125. Hazen-Williams Formula is defined as follows:

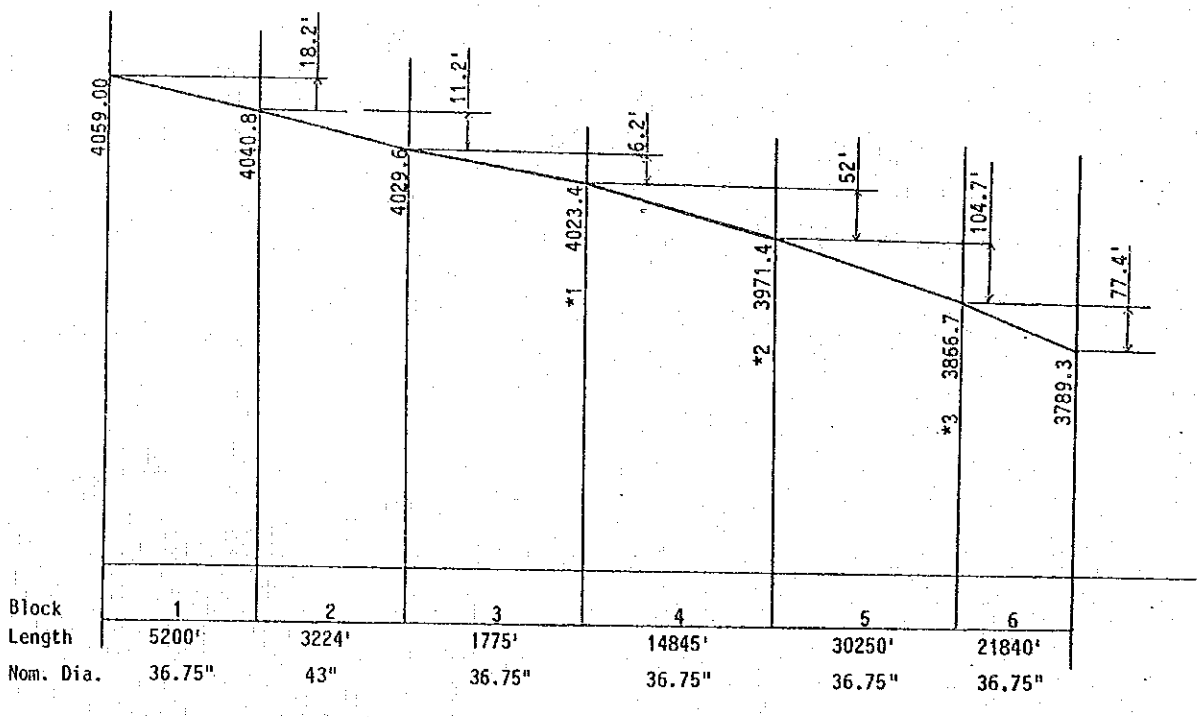
$$C = \{10.66 \times l \div hf \div d^{4.87}\}^{\frac{1}{1.85}} \times Q$$

where
- l = pipe length in m
- hf = friction loss in m
- d = pipe inner diameter
- Q = Capacity in m^3/sec

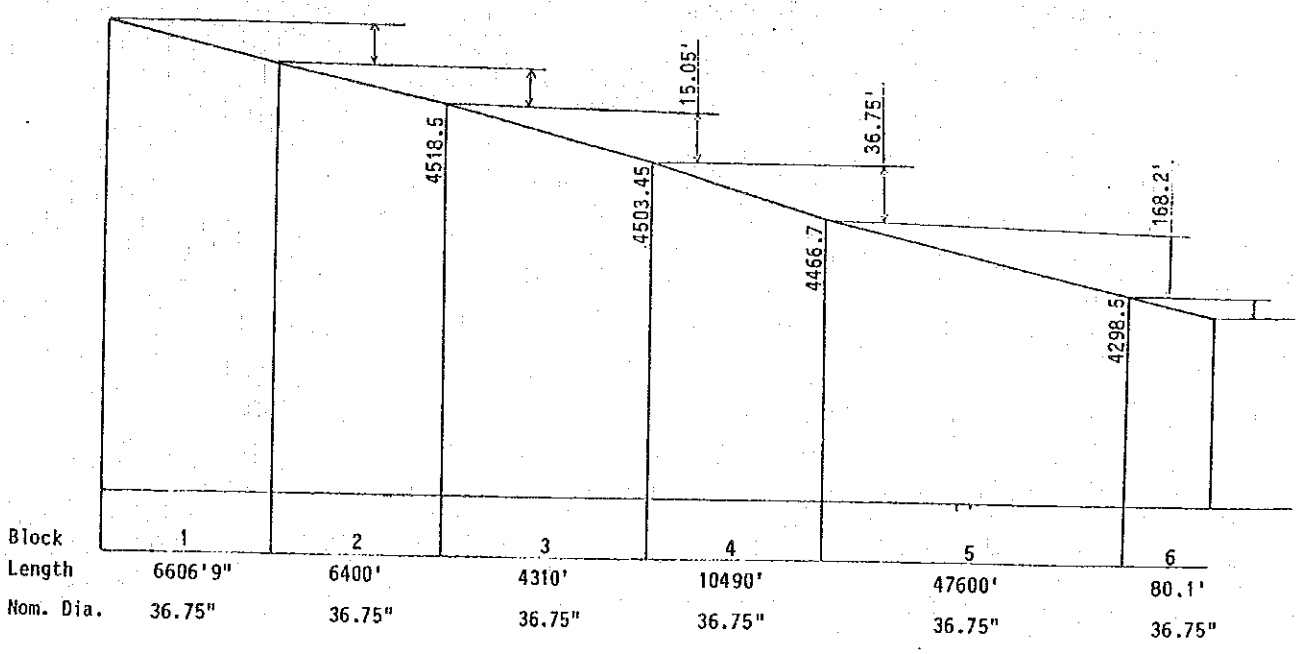
a. Data for Calculation

i) Hydraulic gradient of existing pipeline (frompipeline profile) (Delivered capacity is assumed as Q = 16,680IGPM = 109,208m^3/day).

No.1 PS ~ No.2 PS



No.2 PS ~ Terminal Resrvoir



ii) Loss coefficient of existing pipeline

No.1 P.S ～ No.2 P.S

$Q = 16,680^{IGPM}$

$= 16,680 \times 0.0045465/60\ m^3/sec$

$= 1.2640\ m^3/sec$

Block	l	hf	d	c
1	1,584.96	(18.21) 5.547	0.908	124
2	982.68	(11.21) 3.414	1.0636	82
3	540.99	(63.21) 1.890	0.908	124
4	4,524.76	(52.0) 15.850	0.9112	123
5	9,220.20	(104.71) 31.913	0.9144	122
6	6,656.83	(77.41) 23.592	0.9176	120

No.2 P.S ~ Terminal Reservoir

Q = 1.2640 m^3/s

Block	l	hf	d	c
3	1,313.7	(15.051) 4.587	0.9112	123
4	3,197.4	(36.751) 11.201	0.9144	122
5	14,508.5	(168.21) 51.267	0.9176	120

2. Loss coefficient to be used and pipeline head loss

According to, loss coefficient C value can be 130 for straight pipe not including elbow etc. and can be 110 for pipe including elbow loss.

However, in consideration of calculated C value for existing pipeline, the C value to be used in this design shall be 120.

Pipeline head loss is calculated by the following Hazen-Williams Formula and calculated data is shown in Table 2-1.

$$Hf = 10.666 \times (Q - PH: C)^{1.85} \times (l \div d^{4.87}) \times l$$

As results, each pipeline head loss for both No. 1 and No. 2,

No. 1 High-light pump Hf = 84.81m

No. 2 High-light pump Hf = 84.17m

Table 2.1 Calculated data of pipeline head loss (C = 120)

$Q = 76.5m^3/min = 1.275m^3/sec$

Block	No.1 P.S ~ No.2 P.S			No.2 P.S ~ Terminal Reservair		
	d	e	hf	d	e	hf
1	0.908	1,584.96	6.037	0.908	2,013.7	7.671
2	1.0636	982.68	1.732	0.9112	1,950.7	7.304
3	0.908	540.99	2.061	0.9112	1,313.7	4.919
4	0.9112	4,524.76	16.943	0.9144	3,197.4	11.769
5	0.9144	9,220.2	33.940	0.9176	14,508.5	52.506
6	0.9176	6,656.83	24.091	0.9176	24.4	0.027
Total	$Hf = \Sigma hf = 84.805$			$Hf = \Sigma hf = 84.169$		

3. Total head of pump

Total head for both No. 1 and No. 2 high lift pump are accumulated as follows:

	No. 1 High Lift Pump	No. 2 High Lift Pump
Water Level Condition		
Suction water level	3,298.8'	3,789'
Discharge water level	3,789'	4,298.2'
Static head	149.5m (490.5 feet)	155.2m (509.2m)
Pipeline head loss	84.81	84.17
Station head loss	2.0m	2.0m
Total head	236.3m	241.37m

Though, as shown above, each total head for No. 1 and No. 2 high lift pump has 5m difference, both total head shall be determined 242m as same in consideration of the convenience to be changeable each other between No. 1 and No. 2 pumping station.

4. Motor output

Motor output = $(0.163 \times 25.5m^3/min \times 242m \times 1.15) - PH: 0.86$

$= 1,345 \fallingdotseq 1,350kW$

where Q = Discharge capacity: $22.5m^3/min$

H = Total head: 242m

= Pump efficiency: 86%

APPENDIX 11 WATER HAMMER ANALYSIS

The water hammer analysis in case of being tripped main pump was carried out to operate and maintain safety after rehabilitaton of No. 1 and No. 2 High Lift Pumping Station.

1. Boundary condition

	Unit	No.1 Pumps	No. 2 Pumps
Pump			
Nos. installed		4	4
Nos. Operated		3	3
Discharge Capacity	m^3/min	22.5	22.5
Total Head	m	242	242
Rotating Speed	rpm	1,490	1,490
Pump Efficiency	%	86	86
GD 2	$Kg.m^2$	160	160
Motor			
Output	kW	1,350	1,350
Type		Squirrel cage	squirrel cage
Voltage	V	3,000	3,000
Frequency	Hz	50	50
No. of Poles	P	4	4
GD 2	$Kg.m^2$	57	57
Non-return value			
Nominal dia	mmφ	450	450
Type		Rapid Closure Type	Rapid closure type
Pipeline			
Material		Steel	Steel
Loss Coefficient		C = 120	C = 120
K/EValue		0.01	0.2
(K: Volume modulus of water...2.07 x 10 kg/m^2)			
(E: Young modulus for pipe material ...2.1 x 10 kg/m^2)			
Other condition		Refer to Table 11.1, 11.2, 11.3	Table 11.4, 11.5, 11.6
Conditions at operating Discharge Capacity		76.5m 3/min = 1.275m 3/s	76.5m 3/min = 1.275m 3/s
Suction water level	m	1005.47	1154.88
Discharge water level	m	1154.89	1310.09
Static head	m	149.42	155.21
Pipeline head loss	m	84.8	84.26
Station Head loss	m	7.81	2.53

2. Specification for Water Hammer Protection Devices

By-pass pipeline		Kafue	Chilanga
Initial water level	m	1005.47	1154.88
Diameter of assumed tank	m	30	30
Diameter of by-pass pipe	m	450	450
Loss coefficient to flow out	$m/(m^3/s)$	6,526	6,526
Flywheel GD 2	$Kg.m^2$	1,0000	1,000
Type		Coupling type	Coupling type
Air Valve Type		5"inlet and outlet type	
Set level		Shown in Table 11-1	Shown in Table 11-4
Nos.		Ditto	Ditto
Loss coefficient to flow in	m/(3s)2	130 (assumed)	130 (assumed)
Loss coefficient to flow out	m/(3s)2	6.4 (assumed)	6.4 (assumed)
One-way surge vessel		Chilanga No. 1	Chilanga No. 2
Location point (Distance from pumping station)	(Km)	12.0112	13.5352
Location level (ground level)	(m)	1293.98	1304.4
Initial water level	(m)	1295.86	1306.86
Size	(m)	3 x 3.5 x 3m	7 x 7 x 4m
Nozzle diameter	(m)	250	400
Loss coefficient to flow out	(mm)	88.9	14.53

Table 11.1 (1)
表　11.1 (1)

(Kafue)

NODE	Chainage (10^3ft.)	Chainage (m)	Trench Invent Level(ft)	Trench Invent Level(m)
1	0	0	3289.5	1002.6
2	10	304.8	3225.5	992.3
3	44	1341.12	3257.18	992.79
4	52	1585	3254.5	992
5	74+24	2262.8	3290.0	1002.79
6	83+24	2537.2	3320.0	1011.94
7	84+24	2568	3320.3	1012
8	92+24	2811.5	3336.62	1017.00
9	101+33.9 , 0+65	3108.6	3378.0	1029.614
10	101+33.9 , 4+70	3232.07	3397.89	1035.677
11	101+33.9 , 30	4003.2	3356	1022.909
12	101+33.9 , 42	4369	3362	1024.738
13	101+33.9 , 45	4460.5	3370	1027.176
14	101+33.9 , 48	4551.9	3374	1028.395
15	101+33.9 , 55+28	4773.7	3372	1027.786
16	101+33.9 , 67	5131.0	3372	1027.786
17	101+33.9 , 86	5710.1	3382	1030.834
18	101+33.9 , 102	6197.8	3458	1053.998
19	101+33.9 , 120	6746.4	3417.07	1041.523
20	101+33.9 , 140	7356.0	3498.81	1066.468
21	101+33.9, 149+10	7633.38	3464.70	1056.04
22	101+33.9 , 163	8057.05	3494.50	1065.124
23	101+33.9 , 176	8453.3	3451.45	1052.002

Table 11.1 (2)
表　11.1 (2)

NODE	Chainage (10^3ft)	Chainage (m)	Trench Invent Level(ft)	Trench Invent level (m)
24	101+33.9, 194	9001.9	3510	1069.848
25	218	9733.5	3526.84	1074.981
26	240	10404	3545.33	1080.617
27	258	10952.7	3561.83	1085.646
28	270	11318.4	3551.08	1082.369
29	292	11989	3497.20	1065.947
30	314+97.4	12689.2	3510.85	1070.107
31	332	13208.2	3486.43	1062.664
32	346	13634.9	3506.48	1068.775
33	374	14488.3	3531.54	1076.413
34	402	15341.8	3532	1076.554
35	417	15799	3555.13	1083.604
36	446	16682.9	3566.55	1087.084
37	451+60	16853.58	3564.42	1086.435
38	503+50	18435.5	3610.00	1100.328
39	533	19334.7	3602.03	1097.899
40	557	20066.2	3620.28	1103.461
41	584	20889.1	3676.04	1120.457
42	594	21194	3697.98	1127.144
43	606	21560	3681.12	1122.005
44	624	22108.5	3710.86	1131.07
45	643	22687.5	3721.00	1134.161
46	658	23144.7	3733.83	1138.071
47	670	23510.42	3784.45	1153.5

Table 11.2
表　11.2

(Kafue)

Pipe No.	Node No.	Diameter di (mm)	Thickness t (mm)	a (m/s)	Length l (m)	Head loss(m)	
1	1 → 2	908.05	12.7	1088.1	304.8	1.16	
2	2 → 3	〃	〃	〃	1036.32	3.95	
3	3 → 4	〃	〃	〃	243.88	0.93	
4	4 → 5	1063.63	14.3	1079.1	677.8	1.19	
5	5 → 6	〃	〃	〃	274.4	0.54	
5	6 → 7	〃	〃	〃	30.8	0	
6	7 → 8	908.05	12.7	1088.1	243.5	0.93	
7	8 → 9	〃	〃	〃	297.1	1.13	
8	9 → 10	911.23	11.11	1056.2	123.47	0.46	
9	10 → 11	〃	〃	〃	771.13	2.88	
10	11 → 12	〃	〃	〃	365.8	1.37	
11	12 → 13	〃	〃	〃	91.5	0.34	
12	13 → 14	〃	〃	〃	91.4	0.34	
13	14 → 15	〃	〃	〃	221.8	0.83	
14	15 → 16	〃	〃	〃	357.3	1.33	
15	16 → 17	〃	〃	〃	579.1	2.19	
15	17 → 18	〃	〃	〃	487.7	1.82	
16	18 → 19	〃	〃	〃	548.6	2.05	
17	19 → 20	〃	〃	〃	609.6	2.28	
18	20 → 21	〃	〃	〃	277.38	1.04	
19	21 → 22	914.40	9.53	1018.0	423.67	1.56	
20	22 → 23	〃	〃	〃	396.25	1.45	
21	23 → 24	〃	〃	〃	548.60	2.02	
22	24 → 25	〃	〃	〃	731.6	2.69	

Table 11.3
表　11.3

No.	Pipe Node	di (mm)	t (mm)	a (m/s)	l (m)	loss(m)	備　考
23	25 → 26	914.40	9.53	1018.0	670.5	2.47	
24	26 → 27	↓	↓	↓	548.7	2.02	
25	27 → 28	↓	↓	↓	365.7	1.35	
26	28 → 29	↓	↓	↓	670.6	2.47	29 をなしとする
26	29 → 30	↓	↓	↓	700.2	2.57	29 をなしとする
27	30 → 31	↓	↓	↓	519.0	1.91	
28	31 → 32	↓	↓	↓	426.7	1.57	
29	32 → 33	↓	↓	↓	853.4	3.15	
30	33 → 34	↓	↓	↓	853.5	3.15	
31	34 → 35	↓	↓	↓	457.2	1.68	35 をなしとする
31	35 → 36	↓	↓	↓	883.9	3.25	35 をなしとする
32	36 → 37	↓	↓	↓	170.68	0.63	
33	37 → 38	917.6	7.94	970.6	581.92	5.73	
34	38 → 39	↓	↓	↓	899.2	3.26	
35	39 → 40	↓	↓	↓	731.5	2.65	
36	40 → 41	↓	↓	↓	822.9	2.98	41 をなしとする
36	41 → 42	↓	↓	↓	304.9	1.10	41 をなしとする
37	42 → 43	↓	↓	↓	366.0	1.32	
38	43 → 44	↓	↓	↓	548.5	1.98	
39	44 → 45	↓	↓	↓	579.0	2.10	45 をなしとする
39	45 → 46	↓	↓	↓	457.2	1.65	45 をなしとする
40	46 → 47	↓	↓	↓	365.72	1.32	

Table 11.4 (1)
表　11.4 (1)

NODE	Chainage (10^3ft)	Chainage (m)	Trench Invent Level(ft)	Trench Invent level (m)
1	672-206 9	0	3776.42	1151.05
2	678	245.9	3805	1159.76
3	698	855.5	3785.28	1153.75
4	704	1038.38	3769.56	1148.96
5	718	1465.1	3794.36	1156.52
6	736	2013.7	3880.5	1182.776
7	752	2501.4	3876	1181.405
8	766	2928.1	3904	1189.9
9	777	3263.4	3955	1205.48
10	800	3964.46	3979.60	1212.98
11	803+50	4071.1	3983.50	1214.171
12	820	4574.1	3921.58	1195.3
13	829+40	4860.6	3947.85	1203.305
14	843+10	5278.15	3989.50	1216.00
15	846+60	5384.8	4039.00	1231.087
16	858	5732.3	4023.72	1226.43
17	870	6098.1	4036.62	1230.362
18	877+50	6326.7	4075.50	1242.212
19	904/1	7134.4	4078.0	1242.974
20	914/1	7339.2	4138	1261.3
21	916/1	7500.1	4139	1261.567
22	926/1	7804.9	4096	1248.461
23	934/1	8048.8	4106	1251.509

Table 11.4 (2)
表　11.4 (2)

NODE	Chainage (10^3ft)	Chainage (m)	Trench Invent Level(ft)	Trench Invent level (m)
24	948/1	8475.5	4127.0	1257.91
25	976/1	9328.9	4151.0	1265.225
26	996/1	9938.5	4164	1269.187
27	1024/1	10792.0	4190	1277.112
28	1040/1	11279.7	4208	1282.598
29	1064/1	12011.2	4238	1291.742
30	1086/1	12681.7	4248	1294.79
31	1106/1	13291.3	4265	1299.972
32	1114/1	13535.2	4272	1302.106
33	1168	15181.1	4234.71	1290.740
34	1192	15912.6	4218.68	1285.853
35	1194	15973.6	4217.34	1285.4
36	1218	16705.1	4218.82	1285.896
37	1244	17497.6	4212.11	1283.851
38	1280	18594.9	4212.89	1284.089
39	1306	19387.3	4209.61	1283.089
40	1328	20057.9	4213	1284.122
41	1348	20667.5	4207.25	1282.37
42	1366	21216.1	4213	1284.122
43	1390	21947.7	4227	1288.39
44	1400	22252.5	4244	1293.6
45	1410	22557.3	4273	1302.4
46	1420	22862.1	4280	1304.5
47	1424+80.1	23008.4	4280	1304.5

Table 11.5
表　11.5

(Chilanga)

No.	Pipe Node	di (mm)	t (mm)	a (m/s)	l (m)	loss(m)	
1	1 → 2	908.05	12.7	1088.1	245.9	0.94	
2	2 → 3	〃	〃	〃	609.6	2.32	
3	3 → 4	〃	〃	〃	182.88	2.32	
3	4 → 5	〃	〃	〃	426.72		
4	5 → 6	〃	〃	〃	548.6	2.09	
5	6 → 7	911.23	11.12	1056.2	487.7	1.83	
6	7 → 8	〃	〃	〃	426.7	2.85	
6	8 → 9	〃	〃	〃	335.3		
7	9 → 10	〃	〃	〃	701.06	3.03	
7	10 → 11	〃	〃	〃	106.64		
8	11 → 12	〃	〃	〃	503	2.95	
8	12 → 13	〃	〃	〃	286.5		
9	13 → 14	〃	〃	〃	417.55	1.56	
10	14 → 15	914.40	9.53	1018.0	106.65	0.39	
11	15 → 16	〃	〃	〃	347.5	1.27	
12	16 → 17	〃	〃	〃	365.8	1.35	
13	17 → 18	〃	〃	〃	228.6	0.84	
14	18 → 19	〃	〃	〃	807.7	2.99	
15	19 → 20	〃	〃	〃	204.8	1.35	
15	20 → 21	〃	〃	〃	160.9		
16	21 → 22	〃	〃	〃	304.8	1.12	
17	22 → 23	〃	〃	〃	243.9	0.89	
18	23 → 24	〃	〃	〃	426.7	1.57	
19	24 → 25	917.6	7.94	970.6	853.4	3.09	

Table 11.6
表　11.6

(Chilanga)

No.	Pipe Node	di (mm)	t (mm)	a (m/s)	l (m)	loss(m)	備　考
20	25 → 26	917.6	7.94	970.6	609.6	2.21	
21	26 → 27	〃	〃	〃	853.5	3.09	
22	27 → 28	〃	〃	〃	487.7	1.76	
23	28 → 29	〃	〃	〃	731.5	2.65	
24	29 → 30	〃	〃	〃	670.5	2.42	
25	30 → 31	〃	〃	〃	609.6	2.21	
26	31 → 32	〃	〃	〃	243.9	0.88	
27	32 → 33	〃	〃	〃	1645.9	5.98	
28	33 → 34	〃	〃	〃	731.5	2.64	
29	34 → 35	〃	〃	〃	61.0	2.86	
29	35 → 36	〃	〃	〃	731.5		
30	36 → 37	〃	〃	〃	792.5	2.86	
31	37 → 38	〃	〃	〃	1097.3	3.98	
32	38 → 39	〃	〃	〃	792.4	2.86	
33	39 → 40	〃	〃	〃	670.6	2.43	
34	40 → 41	〃	〃	〃	609.6	2.21	
35	41 → 42	〃	〃	〃	548.6	1.98	
36	42 → 43	〃	〃	〃	731.6	2.64	
37	43 → 44	〃	〃	〃	304.8	3.85	
37	44 → 45	〃	〃	〃	304.8		
37	45 → 46	〃	〃	〃	304.8		
37	46 → 47	〃	〃	〃	146.3		

3. Result and Recommendation
The result and recommended protection devices are shown below:

No. 1 P.S (Kafue) - No.2 P.S (Chilanga)

Case / Countermeture	1	2	3	4
Existing bypass-pipe Water level 1,005.47 pipe 0450	0	0		0
Existing Air valve 5 double orifice type air valve				0
Fly wheel		0 GD2=5,000Kg-m2		GD2=5,000Kg-m2
Air chamber			0 Volume=30m^3 Nos. 2 Nos.	
One-way surge tank				
Result	Negative pressure is exceeded 10m in whole pipeline	Negative pressure is exceeded 10m and mass of flywheel is too big to manufacture	Negative pressure is not exceeded 6m, However, it is very difficult to keep the space to install the air chamber facilities and to maintain easily	Negative pressure is not exceeded 7m. This method is recommended under the condition that good maintenance for air valve shall be carried out.
	Not Acceptable.	Not Acceptable.	Not recommendable.	

(Refer to Fig. 11.1)

No.2 P.S (Chilanga) - Terminal Reservoir (Lusaka)

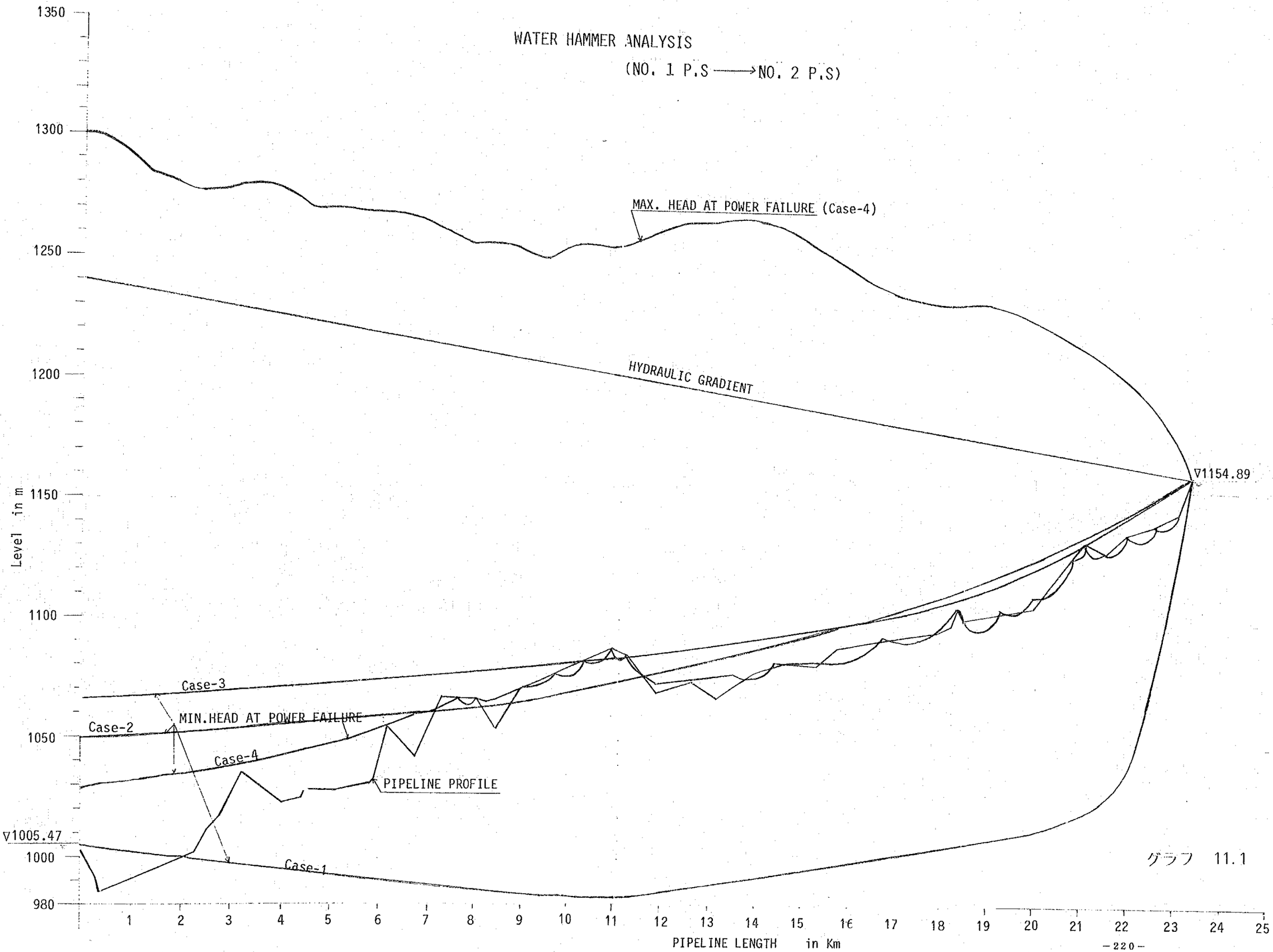
Case / Countermeasure	1	2	3	4	5	6
Existing Bypass-pipe Water level 1,154.88 pipe ϕ450	0	0		0	0	0
Exsisting Air Valve 5 double orifice type air valve		0	0 It is assumed that the air valve at 13.5 Km from pumping station is only available	0 0	0 0	0 0
Fly Wheel		GD2=5,000 Kgm^2		GD2=1,000 Kgm^2 Flywheel type coupling	GD2=1,000 Kgm^2	GD2=1,000
Air Chamber			0 Volume 30m^3 Nos. 3Nos			
One-Way Surge Tank						

Case / Countermeasure	1	2	3	4	5	6
Result	Negative pressure is exceeded 10m in whole pipeline.	Negative pressure is exceeded 10m in the pipe-line between 5 - 22Km distance from pumping station, and size of fly-wheel is too big to manufacture.	Negative pressure is not exceed 7m however, it is very difficult to keep the space to install the air chamber facilities and to main-tain easily.	Negative pressure is exceeded 10m in almost pipeline.	Negative pressure is exceeded 10m at the point of 13Km from pumping station.	Negative pressure is not exceeded 7m. This method is recommended under the condition that good maintenance for air valve shall be carried out.
	Not Acceptable.	Not Acceptable.	Not Acceptable.	Not Acceptable.	Not Acceptable.	

(Refer to Fig. 11.2)

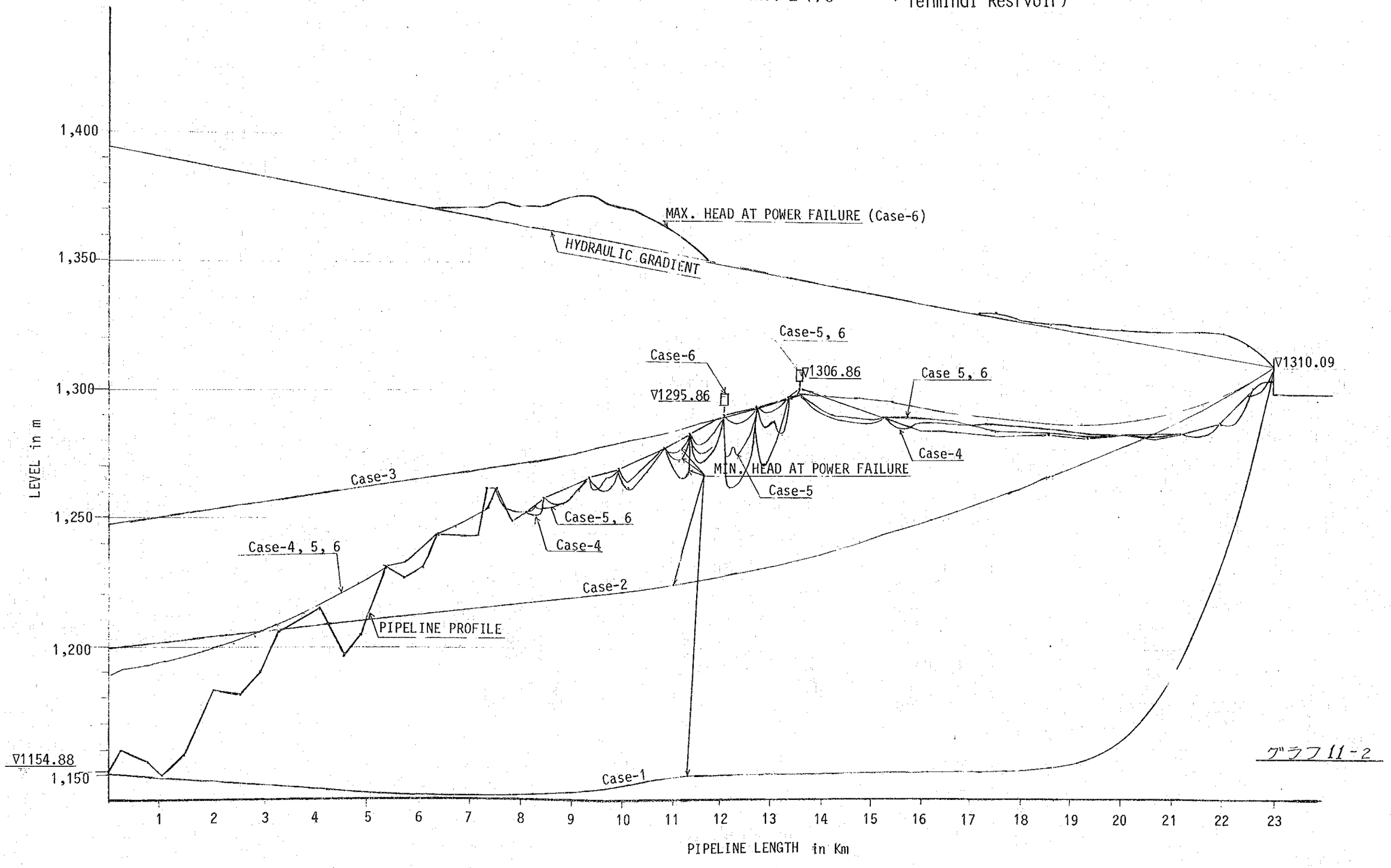
WATER HAMMER ANALYSIS

(NO. 1 P.S ⟶ NO. 2 P.S)



グラフ 11.1

WATER HAMMER ANALYSIS (NO. 2 P/S ——→ Terminal Resrvoir)



グラフ 11-2

APPENDIX 12 DETERMINATION OF DISCHARGE VALVE DIAMETER

(1) Selectiondiameterbymaximum flowvelocitythroughdischarge valve.

Generally, maximum flow velocity through discharge valve will be below 6m/sec.

Maximum capacity for one unit is 31.0m/min in the case of 2 pumps operating and discharge valve 100% opening condition as shown in pump characteristic curve. At the above condition, minimum diameter of discharge valve will be as below

$$(\pi / 4)\, d^2 \times v \times 60 = Q$$

$$d = \{ (4 \times Q) \div (\pi \times v \times 60) \}^{1/2}$$

$$= 0.331\text{mm}.$$

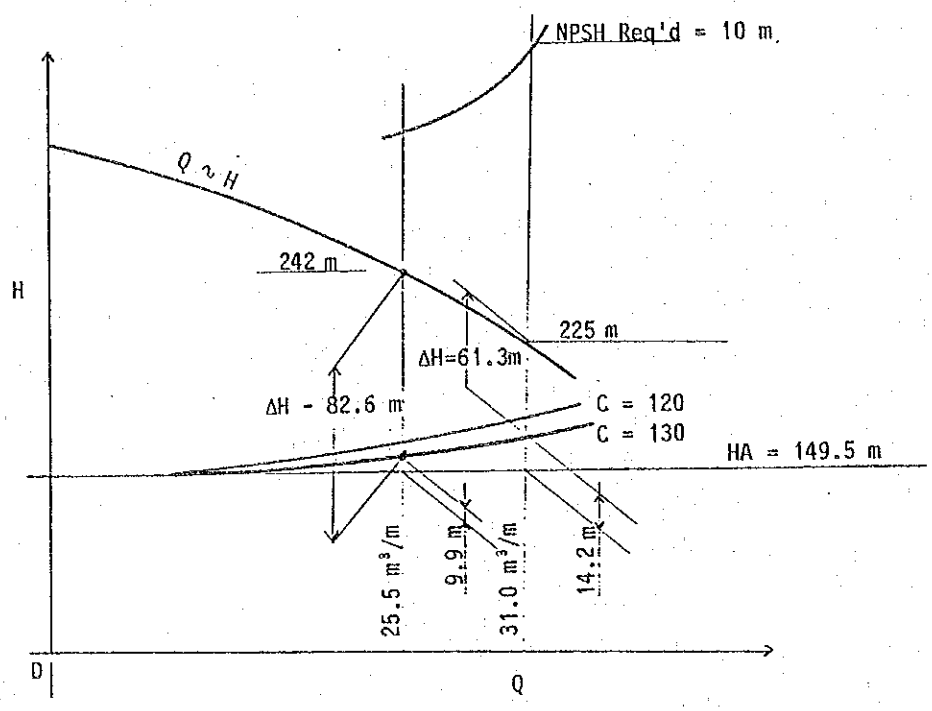
d	mm	350	400	450
v	m/s	5.37	4.11	3.25

On the other hand, as maximum flow velocity through non-return valve being installed between pump and discharge cone valve should be below 4m/sec, the diameter of non-return valve is selected 450mm dia. The diameter of cone valve is selected 400mm dia. in consideration of the space for installation.

(2) Selection diameter by pump operating range

In this clause, C value is used both 120 and 130 (C ≠ 30 is the worst case).

Discharge capacity in case of 2 pumps operation condition and C = 130 will be 69m^3/min/2 unit, 34.5m^3/min/one unit. But at this operating point pump can not be operated continuously because of the valve of NPSH required. Maximum capacity shall be limited 31.0m^3/min.

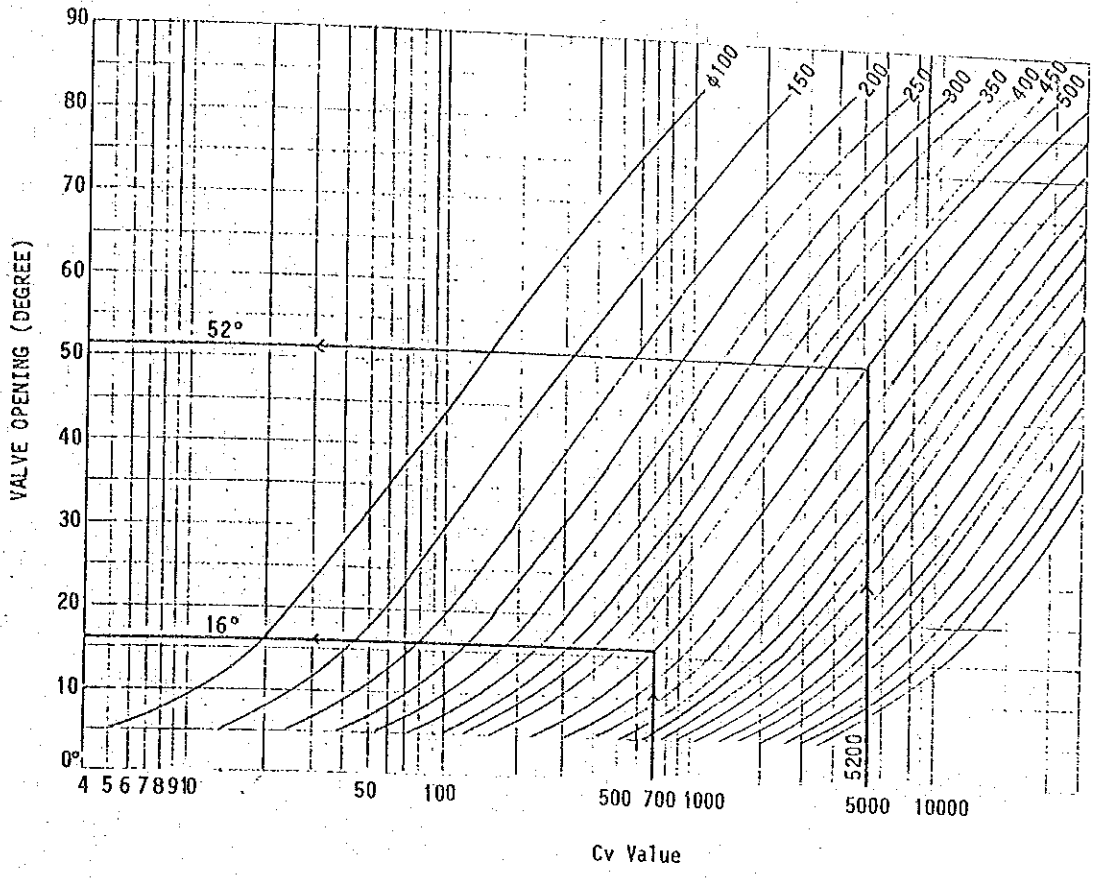


Valve opening ratio to control the discharge capacity to 31m^3/min and the safety against cavitation at this capacity are confirmed as follows:

	C = 120	C = 130
Discharge Capacity for one unit	25.5	31.0
Loss head	82.6	61.3
Pressure at primary side	242	225
Pressure at secondary side	149.5 + 9.9 = 159.4	149.5 + 14.2 = 163.7
Valve opening ratio	27	35
Cavitation coefficient	2.05	2.83
Critical cavitation coefficient	1.05	1.2
Result (KAV > Kreg)	Safety	Safety

(NOTES) In Fig.12-1, the relation between Cv and valve opening ratio, and the relationship between valve opening ratio and cavitation coefficient are shown.

In Fig.12-2 the system curve to show pump operating point is shown.


VALVE OPENING (DEGREE)
90
80
70
60
50
40
30
20
10
0°
52°
16°
φ100
150
200
250
300
350
400
450
500
4 5 6 7 8 9 10
50
100
500 700 1000
5000
10000
5200
Cv Value

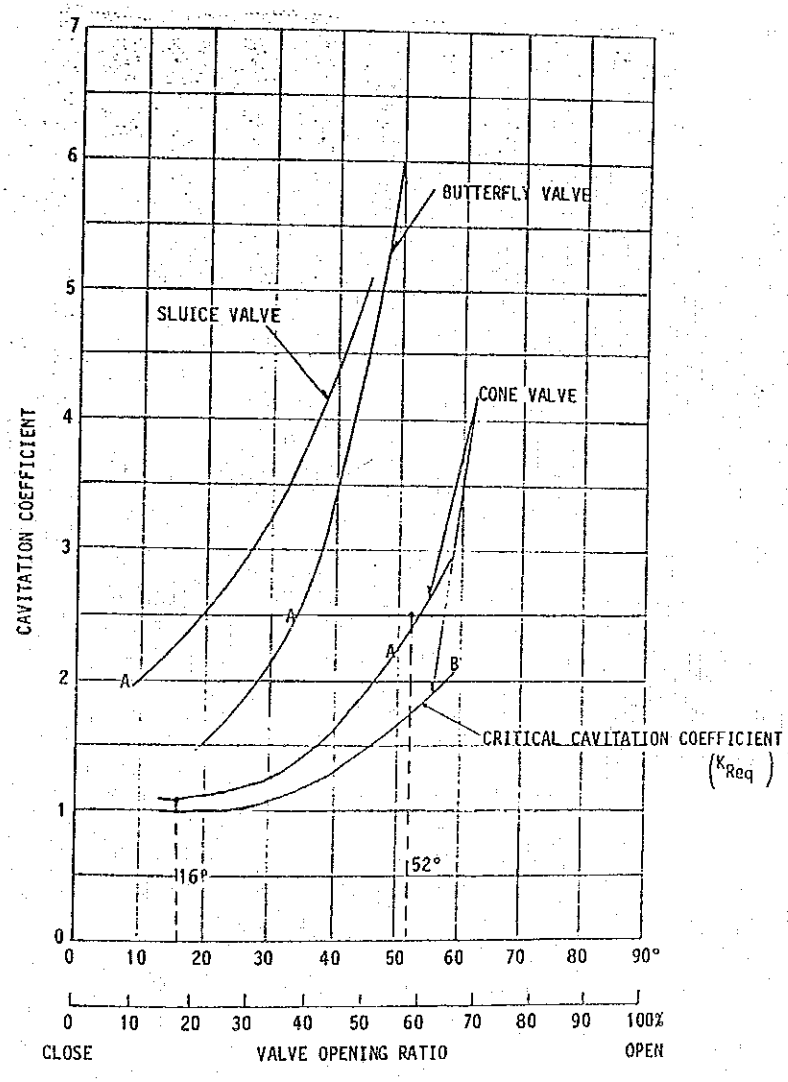

CAVITATION COEFFICIENT
7
6
5
4
3
2
1
0
BUTTERFLY VALVE
SLUICE VALVE
CONE VALVE
A
A
A
B
CRITICAL CAVITATION COEFFICIENT
(K Req)
16°
52°
0 10 20 30 40 50 60 70 80 90°
0 10 20 30 40 50 60 70 80 90 100%
CLOSE
VALVE OPENING RATIO
OPEN

Fig. 12 - 1

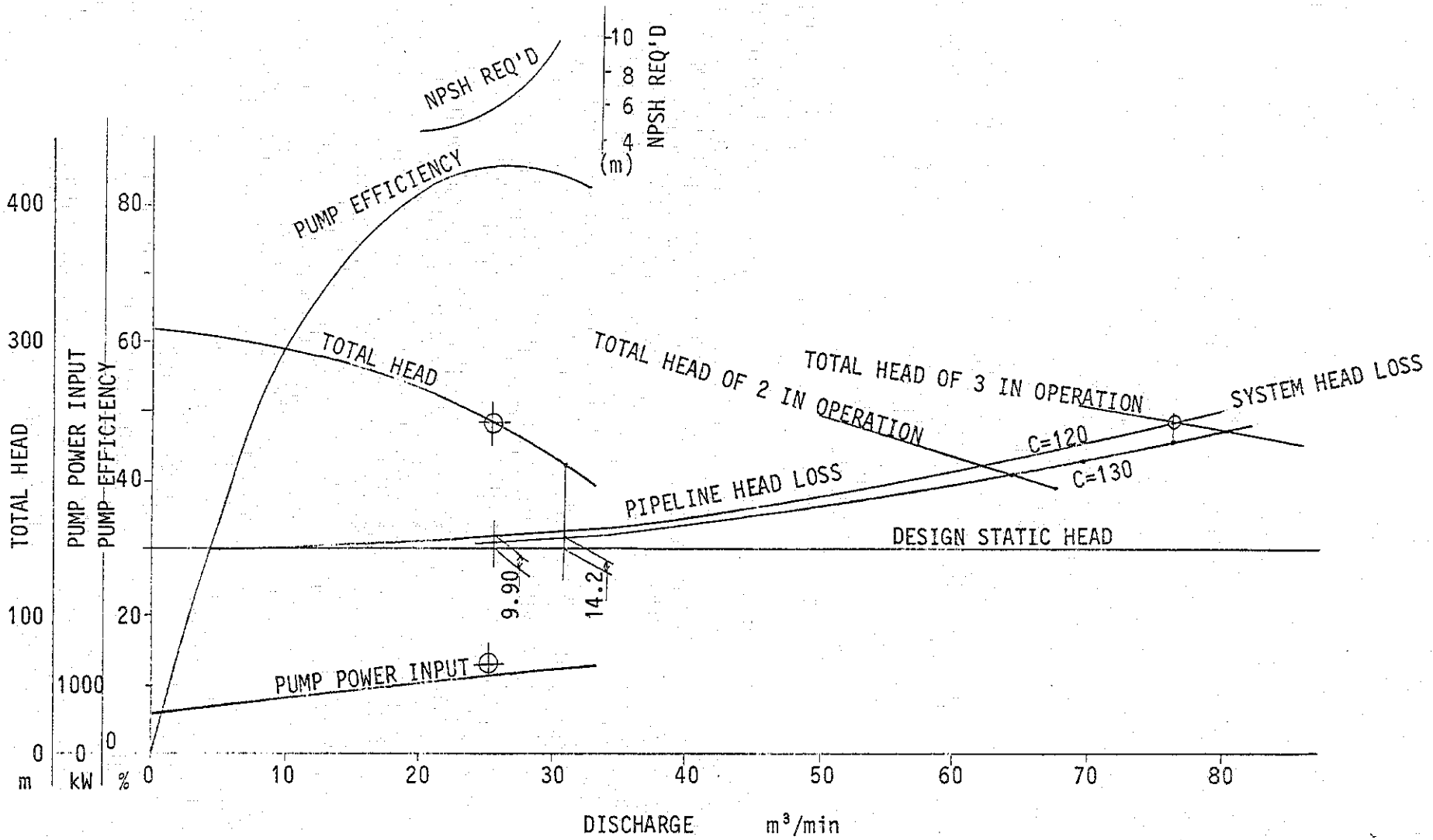

NPSH REQ'D
10
8
6
4
(m)
NPSH REQ'D
PUMP EFFICIENCY
TOTAL HEAD
TOTAL HEAD OF 2 IN OPERATION
TOTAL HEAD OF 3 IN OPERATION
SYSTEM HEAD LOSS
C=120
C=130
PIPELINE HEAD LOSS
DESIGN STATIC HEAD
9.90m
14.2m
PUMP POWER INPUT
TOTAL HEAD
PUMP POWER INPUT
PUMP EFFICIENCY
400
300
100
0
m
1000
0
kW
80
60
40
20
0
%
0
10
20
30
40
50
60
70
80
DISCHARGE m³/min

Fig. 12.- 2

Appendix 13 Calculation of 33/3.3kV Power Transformer Capacity

1. Conditions of Calculation

1) 2 bank system 1..... normally use
1..... stand-by

2) Main loads are following:

a. High lift pumps 1,350kW X 4 sets (1 set stand-by)

Motor charactarisic

Efficiency at full load	95%
Power factor at full load	95%
Starting power factor	0.3
Starting current	6 times of full load current.

b. 300kVA auxiliary transformer 2 sets

c. Intake pumps 315kW X 4 sets

Motor charactaristic

Efficiency at full load	93%
Power factor at full load	86%

3) Starting system for high lift pump is reactor (65% Top)

2. Calculation

Total capacity: T (kVA)

$$= [1,350/(0.95 \times 0.95)] \times 3 + 300 \times 2 + [315/(0.93 \times 0.86)] \times 4$$
$$= 6,663$$

Expecting 10% allowance

$$T = 6,663 \times 1.1 = 7,329 \text{ (kVA)}$$

i.e., transformer capacity shall be 7,500 (kVA)

3. Examination for Voltage Drop

Voltage drop (E) at the secondary terminal of the transformer shown following calculation formula

$$E = 1/T\ [R\ (Sb\cos\theta b + Sm\cos\theta m) + (Sb\sin\theta b + Sm\sin\theta m)]$$

E: voltage drop rate (%)
T: transformer capacity
R: percent resistance of transformer

X: percent reactance of transformer

Sb: basic load capacity

Sm: starting capacity

$\cos\theta$b: basic load power factor

$\cos\theta$m: starting load power factor

1) percent impedance of the transformer 7.5%
percent resistance R: 1.47
percent reactance X: 7.35

2) basic load capacity Sb and starting capacity Sm

$$Sb = [1,350/ (0.95 \times 0.95)] \times 2 + [315/ (0.93 \times 0.86)] \times 4$$
$$= 5.147 \text{ [KVA]}$$
$$Sm = 1,350/ (0.95 \times 0.95) \times 6 \times 0.65$$
$$= 5.834 \text{ [KVA]}$$

3) basic load power factor $\cos b = 0.8$, $\cos m = 0.3 \times 0.65 = 0.195$

voltage drop rate E is as follows:

$$E = 1/7,500 [1.47 (5.167 \times 0.8 - 5.834 \times 0.195) + 7.35 (5.167 \times 0.6 - 5.834 \times 0.98)]$$
$$= 9.67 [\%]$$

starting voltage drop of less than 10% is OK.

Therefore, transformer of 7.5 MVA is used.