4-1-4 Analysis of mining cost

Mining cost for 5 years ('88～'92) is listed in Table 28. Detail costs of stripping, heavy-machines and salary of management are shown respectively in Table 29, 30 and 31 respectively. According to these tables, we find every cost almost unchanged until 1990. After then, some items abruptly increased in 1991, and other items increased in 1992.

● Items increased in 1991

Dipper-tooth, electricity, labor, additional labor, insurance, costs related to heavy machines and costs related to engineers and staff.

● Items increased in 1992

Explosives, fuse, rods and transportation cost.

Big inflation in 1991 was due to confusion caused by social change from planned economy to market economy, but we couldn't see the reason why the explosives cost increased in 1992. Increase of transportation cost was presumed to be due to inflation of labor and parts at Department of Transportation. As exchange of tugrik to dollar, however, was cut down more than 50 times during this time, mining cost seemed to be cut down on base of dollar.

In costs related to heavy machines, fuel and repair cost for Department of Transportation are remarkable. Although many parts are deficient in repair shop, cost for parts purchase was unchanged. This was considered to be due to marked inflation.

Table 28 Mining Cost for last 5 years

cost item	unit	1988 (output 17,277,000t)				1989 (output 17,787,500t)				1990 (output 19,261,000t)				1991 (output 13,310,000t)				1992 (output 16,875,000t)			
		unit consumable	unit price	consumed amount	sum (1,000Tg)	unit consumab	unit price	consumed amount	sum (1,000Tg)	unit consumab	unit price	consumed amount	sum (1,000Tg)	unit consumab	unit price	consumed amount	sum (1,000Tg)	unit consumab	unit price	consumed amount	sum (1,000Tg)
1.material					11,690				9,572				9,587				6,046				129,086
									0.82				1.00				0.63				21.35
explosives	kg	0.186	2.402	3,221,412	7,737	0.179	2.017	3,181,623	6,417	0.166	2.076	3,188,893	6,621	0.126	2.336	1,672,241	3,906	0.201	32.91	3,398,445	111,841
(%)						0.96	0.84	0.99	0.83	0.93	1.03	1.00	1.03	0.76	1.13	0.52	0.59	1.60	14.09	2.03	28.64
fuse	m	0.0228	0.6	393,581	236	0.0228	0.529	386,970	205	0.02	0.522	383,577	200	0.015	0.528	196,376	104	0.025	4.689	425,865	1,997
(%)						1.00	0.88	0.98	0.87	0.88	0.99	0.99	0.98	0.75	1.01	0.51	0.52	1.67	8.88	2.17	19.25
detonator	pcs.	0.175	1.058	3,026	3	0.18	0.905	3,204	3	0.162	0.867	3,115	3	0.127	0.768	1,693	1	0.223	0.823	3,766	3
(%)						1.03	0.86	1.06	0.91	0.90	0.96	0.97	0.93	0.78	0.89	0.54	0.48	1.76	1.07	2.22	2.38
bit	pcs.	0.0163	8,970	281	2,521	0.0152	7,666	271	2,078	0.014	7,666	261	2,001	0.0116	8,873	154	1,366	0.0177	20,456	298	6,096
(%)						0.93	0.85	0.96	0.82	0.92	1.00	0.96	0.96	0.83	1.16	0.59	0.68	1.53	2.31	1.94	4.46
rod	pcs.	0.0016	18,807	27	508	0.00152	15,196	27	410	0.0014	15,196	27	410	0.0014	15,237	19	290	0.002	89,794	34	3,053
(%)						0.95	0.81	1.00	0.81	0.92	1.00	1.00	1.00	1.00	1.00	0.70	0.71	1.43	5.89	1.79	10.55
dipper-teeth	pcs.	0.0159	859	274	235	0.0159	691	282	195	0.016	705	304	214	0.0172	1552	229	355	0.0143	4018	241	968
(%)						1.00	0.80	1.03	0.83	1.01	1.02	1.08	1.10	1.08	2.20	0.75	1.66	0.83	2.59	1.05	2.73
etc					450				265				138				24				5,128
(%)									0.59				0.52				0.18				212.78
2.electricity	kwh	0.475	0.188	8,213,187	1,542	0.484	0.188	8,603,203	1,618	0.443	0.1889	8,539,207	1,613	0.472	0.522	6,279,703	3,276	0.44	1.79	7,431,421	13,303
(%)						1.02	1.00	1.05	1.05	0.92	1.00	0.99	1.00	1.07	2.76	0.74	2.03	0.93	3.43	1.18	4.06
3.labor					1,012				1,051				1,101				2,442				7,682
(%)									1.04				1.05				2.22				3.15
4.add. labor					90				164				284				425				688
(%)									1.82				1.73				1.50				1.62
5.insurance					120				125				130				396				1,133
(%)									1.04				1.04				3.05				2.86
6.amotization					39,105				16,210				26,270				13,360				14,775
(%)									0.41				1.62				0.51				1.11
pre-stripping1					5,181				5,604				5,725				7,687				5,674
(%)									1.08				1.02				1.34				0.74
pre-stripping2					28,249				4,933				14,869				0				0
(%)									0.17				3.01				0.00				0.00
equipment					5,675				5,673				5,676				5,673				9,101
(%)									1.00				1.00				1.00				1.60
7.transp.	t·km	1.618	0.706	27,954,000	19,744	1.595	0.696	28,370,000	19,749	1.703	0.645	32,847,000	21,189	1.739	1.209	23,146,000	27,990	1.726	3.319	29,130,000	96,697
(%)						0.99	0.99	1.01	1.00	1.07	0.93	1.16	1.07	1.02	1.87	0.70	1.32	0.99	2.75	1.26	3.45
8.stripping					47,802				45,450				44,872				38,007				137,488
(%)									0.95				0.99				0.85				3.62
9.geology					5,644				5,204				3,246				2,075				6,062
(%)									0.92				0.62				0.64				2.92
10.heavy mach.					7,024				6,266				6,444				17,894				47,980
(%)									0.89				1.03				2.78				2.68
11.staff-salary					1,031				1,295				1,222				3,325				12,434
(%)									1.26				0.94				2.72				3.74
total					134,804				106,704				115,958				115,236				467,597
(%)									0.79				1.09				0.99				4.06

Table 29 Stripping Detail Cost for last 5 years (8.stripping)

cost item	unit	1988 (stripping 5,190,000m3)				1989 ([illegible] 6,468,700m3)				1990 (stripping 6,468,000m3)				1991 (stripping 3,932,600m3)				1992 (stripping 2,672,000m3)			
		unit consumable	unit price	consumed amount	sum (1,000Tg)	unit consumab	unit price	consumed amount	sum (1,000Tg)	unit consumab	unit price	consumed amount	sum (1,000Tg)	unit consumab	unit price	consumed amount	sum (1,000Tg)	unit consumab	unit price	consumed amount	sum (1,000Tg)
1.material					10,761				8,580				8,211				4,737				52,053
									0.80				0.96				0.59				10.99
explosives	kg	0.464	2.402	2,867,996	6,883	0.445	2.014	2,881,066	5,804	0.421	2.062	2,720,601	5,609	0.409	2.126	1,605,263	3,412	0.501	34.08	1,352,289	46,031
(%)						0.96	0.84	1.00	0.84	0.95	1.02	0.94	0.97	0.97	1.03	0.59	0.61	1.23	16.03	0.84	13.50
fuse	m	0.057	0.602	349,488	211	0.054	0.529	349,949	185	0.051	0.521	327,510	171	0.048	0.529	187,558	93	0.064	5.316	170,216	905
(%)						0.95	0.88	1.00	0.88	0.94	0.98	0.94	0.92	0.94	1.02	0.57	6.58	1.33	10.05	0.91	9.12
detonator	pcs.	0.441	1.065	2,723	3	0.449	0.894	2,907	3	0.489	0.869	2,616	2	0.402	0.887	1,579	1	0.566	0.725	1,517	1
(%)						1.02	0.84	1.07	0.90	0.91	0.97	0.91	0.88	0.99	1.02	0.60	0.61	1.41	0.82	0.96	0.71
bit	pcs.	0.0417	8,873	258	2,289	0.0376	7,666	243	1,863	0.035	7,666	228	1,733	0.0316	8,033	125	1,004	0.0498	20,255	133	882
(%)						0.90	0.86	0.94	0.81	0.93	1.00	0.93	0.93	0.91	1.05	0.55	0.58	1.57	2.52	1.06	0.88
rod	pcs.	0.0039	17,967	24	431	0.0034	14,782	22	325	0.0037	15,075	24	362	0.0031	15,075	12	181	0.0037	88,170	10	2,694
(%)						0.87	0.82	0.92	0.75	1.09	1.02	1.09	1.11	0.84	1.00	0.50	0.50	1.19	5.85	0.83	14.89
dipper-teeth	pcs.	0.0408	817	252	206	0.0402	693	260	181	0.041	703	256	187	0.0387	1169	152	178	0.0382	4520	102	882
(%)						0.99	0.85	1.03	0.88	1.02	1.02	1.02	1.03	0.94	1.65	0.58	0.55	0.99	3.87	0.67	4.36
etc					737				219				147				-139				1,030
(%)									0.30				0.67				-0.94				—
2.electricity	kwh	1.188	0.188	7,345,125	1,380	1.21	0.188	7,854,869	1,477	1.129	0.1907	7,303,725	1,393	1.113	0.525	4,375,748	2,297	1.09	2.019	2,913,707	5,882
(%)						1.02	1.00	1.07	1.07	0.93	1.01	0.93	0.94	0.99	2.75	0.60	1.65	0.98	3.85	0.67	2.56
3.labor					924				959				969				1,503				3,002
(%)									1.04				1.01				1.55				2.00
4.add. labor					77				81				78				131				267
(%)									1.05				0.96				1.68				2.04
5.insurance					104				112				111				254				429
(%)									1.08				0.99				2.29				1.69
6.amotization					4,804				5,089				4,931				3,479				3,469
(%)									1.06				0.97				0.71				1.00
pre-stripping1					0				0				0				0				0
(%)																					
pre-stripping2					0				0				0				0				0
(%)																					
equipment					4,804				5,089				4,931				3,479				3,489
(%)									1.06				0.97				0.71				1.00
7.transp.	t·km	5.23	0.705	32,323,000	22,791	4.932	0.781	31,903,600	22,369	5.434	0.644	35,180,000	22,647	5.709	0.774	22,450,000	17,380	6.027	3.037	16,105,000	48,905
(%)						0.94	0.95	0.99	0.98	1.10	0.92	1.10	1.01	1.05	1.29	0.64	0.77	1.06	3.92	0.72	2.81
8.stripping					0				0				0				0				0
(%)																					
9.geology					0				0				0				0				0
(%)																					
10.heavy mach.					6,059				5,623				5,477				6,944				18,734
(%)									0.93				0.97				1.27				2.70
11.staff-salary					903				1,160				1,055				1,280				5,014
(%)									1.28				0.91				1.21				3.92
total					47,802				45,450				44,872				38,005				137,755
(%)									0.95				0.99				0.85				3.62

Table 30 Heavy Machines

cost item	1988	1989	1990	1991	1992
1.daily repair	2,688	2,884	2,655	5,212	17,667
labor	193	199	226	808	1,581
insurance	20	20	22	115	213
fuel	2,475	2,665	2,407	4,289	15,873
2.heavy repair	8,798	7,470	8,125	10,476	13,988
labor	710	721	684	1,181	3,927
insurance	70	72	68	170	520
parts	6,093	4,990	5,708	6,817	5,827
workshop	1,909	1,667	1,650	1,872	2,616
computer	16	20	15	436	1,098
3.consumable	134	193	57	151	44
4.transp.repair	1,405	1,612	1,419	9,324	33,985
except truck	-	-	-	3,394	6,611
small truck	-	-	-	5,930	27,374
6.electricity	-	-	-	105	882
7.tamping	-	-330	-378	-648	-887
8.road watering	-	-	-	16	-
9.etc	57	60	72	202	1034
total	13,082	11,889	11,950	24,838	66,713

Table 31 Staff Salary

cost item	1988	1989	1990	1991	1992
1.staff-salary	1,061	1,092	1,192	2,486	
basic+add.	938	969	1,054	2,122	
insurance	123	123	138	364	
2.allowance	98	108	89	199	
3.condition	563	739	845	1,162	
material	148	355	497	465	
heating	104	107	187	344	
water	311	277	161	353	
4.repair	112	390	12	598	
5.consumable	98	82	125	167	
6.income	0	0	-18	-35	
7.travelling	2	44	32	28	
total	1,934	2,455	2,277	4,605	

4-2 Mineral Processing

4-2-1 Production Process

(1) Present condition of the facilities

The Erdenet Mine Mineral Processing Plant consists of Units No.1 to No. 4 constructed between 1974 and 1983, and Unit No.5 constructed in 1988. The total processing capacity of these five units is 20 million tons/year (4 M tons/unit· year × 5units).

(2) Ore Minerals

The main minerals are the secondary sulfide minerals such as chalcocite (Cu_2S) and covellite (CuS), and the primary sulfide mineral such as chalcopyrite ($CuFeS_2$) and molybdenite (MoS_2). As mining progresses from the upper part of the deposit, which is rich in secondary sulfide mineral, toward the deeper part of the deposit, primary minerals become dominant. It is expected that chalcopyrite will account for more than 50% of copper minerals mined by 1995.

(3) Organization and Personnel

The organization of the mineral processing section is shown in Figure 14, and the number of personnel is shown in Table 32.

(4) Mineral Processing Flow

① Crushing and Grinding

Units No.1 to No.4 employ an orthodox combination of two-stage crushing using corn crushers and closed circuit grinding and classification using ball mills and hydrocyclones. On the contrary, Unit No. 5 employs advanced technology.

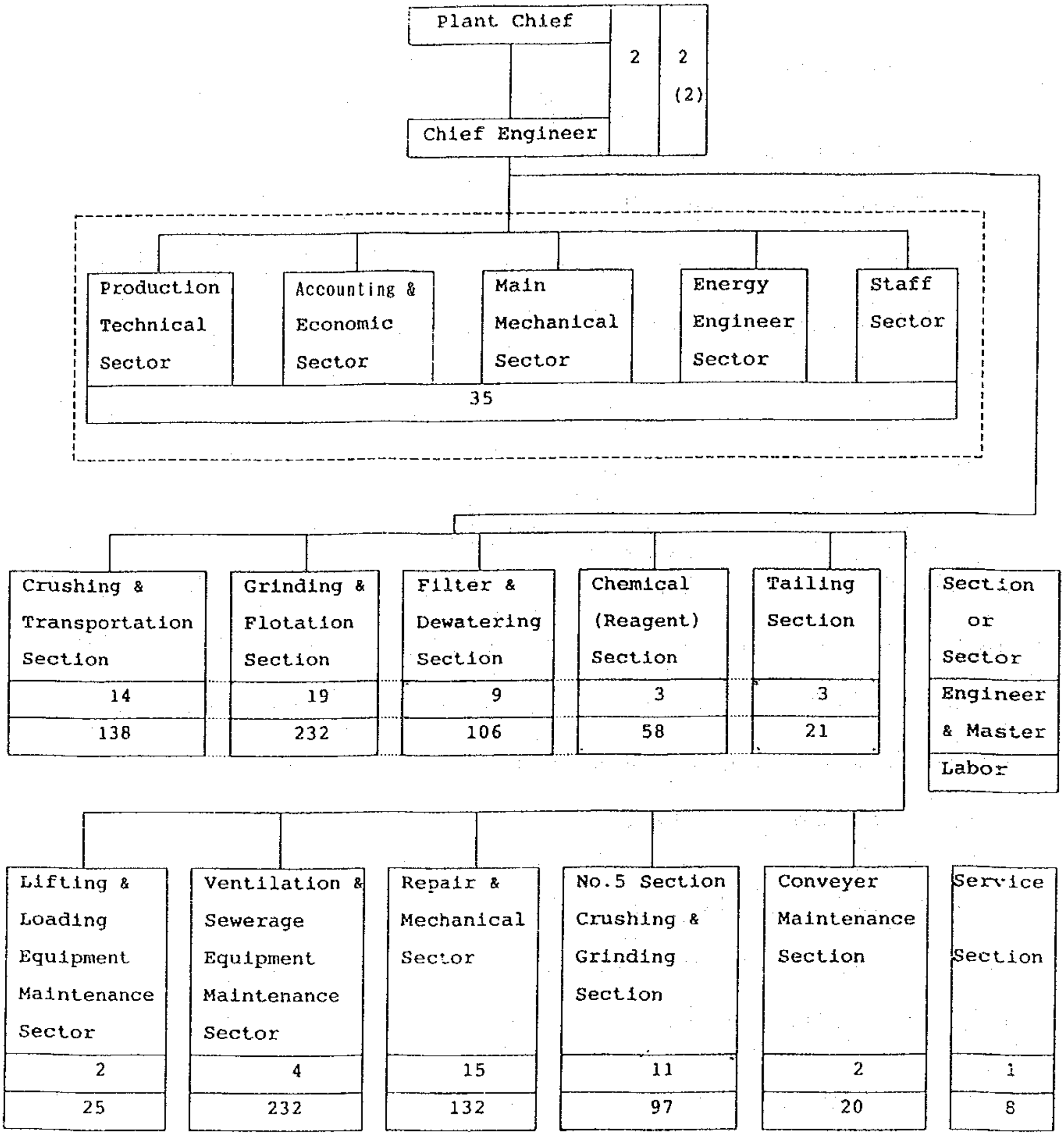


Fig 14 Organization of Mineral Processing Section

Table 32 Man Power of Mineral Processing Section

Section and/or Sector	Engineer or Master	Worker		Total
		Mongolian	Russian	
Crushing & Transportation	14	127	11	152
No.5 Section Crushing & Grinding	11	70	27(6)	108
Grinding & Flotation	19	195	37(4)	251
Chemical (Reagent) Preparing	3	55	3	61
Filtering-Dewatering	9	97	9	115
Ventilation & Sewerage Eqpt.	4	195	37(4)	236
Repare & Mechanical	15	91	41	147
Lifting & Loading Eqpt.	2	18	7	27
Conveyer Maintenance	2	17	3(1)	22
Tailing	3	11	10	24
Sub Total	82	876	185	1,143
Staff				35
Total				1,178

This modern plant, which consists of a jaw crusher, autogenous mill, ball mill, and hydrocyclone, produces flotation slurry consisting of 65 % – 200 mesh fine ore from –250 mm ore feed.

Figure 15 shows the crushing and grinding flow of Units No. 1 to No.4. Figure 16 shows the crushing and grinding flow of Unit No.5.

② Flotation

A standard flotation method is adopted in all units; bulk flotation of copper-molybdenum bulk concentrate followed by separation flotation of molybdenum and copper. To overcome the difficulty of separating molybdenum from copper, the Erdenet plant employs a unique thermo-treatment method using steam to prevent copper (secondary sulfide mineral) floating.

Figure 17 is a flow sheet of the molybdenum/copper separation flotation.

Unit No.6 (flotation circuit only; production capacity: 4 million tons/year) is now under construction. Provisions have been partially procured, in Unit No. 6, for the introduction of three countries' flotation machines – a large scale one made by Outokumpu Oy, and one each of Russian and Chinese manufacture.

The reasons for introducing several types of machine from 3 different countries are to compare the performance of Russian with non-Russian machines and to find a substitute and carry out the renovation and upgrading work of the obsolescent units 1 – 4 (4M tons/year/unit →4.5M tons/year/unit).

Unit No.6 was to be completed in 1993. However, there has been difficulty raising funds for procuring the China-made flotation machine, the completion is likely to be delayed. Figure 18 shows the flotation flow and the type of flotation machine to be used at Unit No. 6.

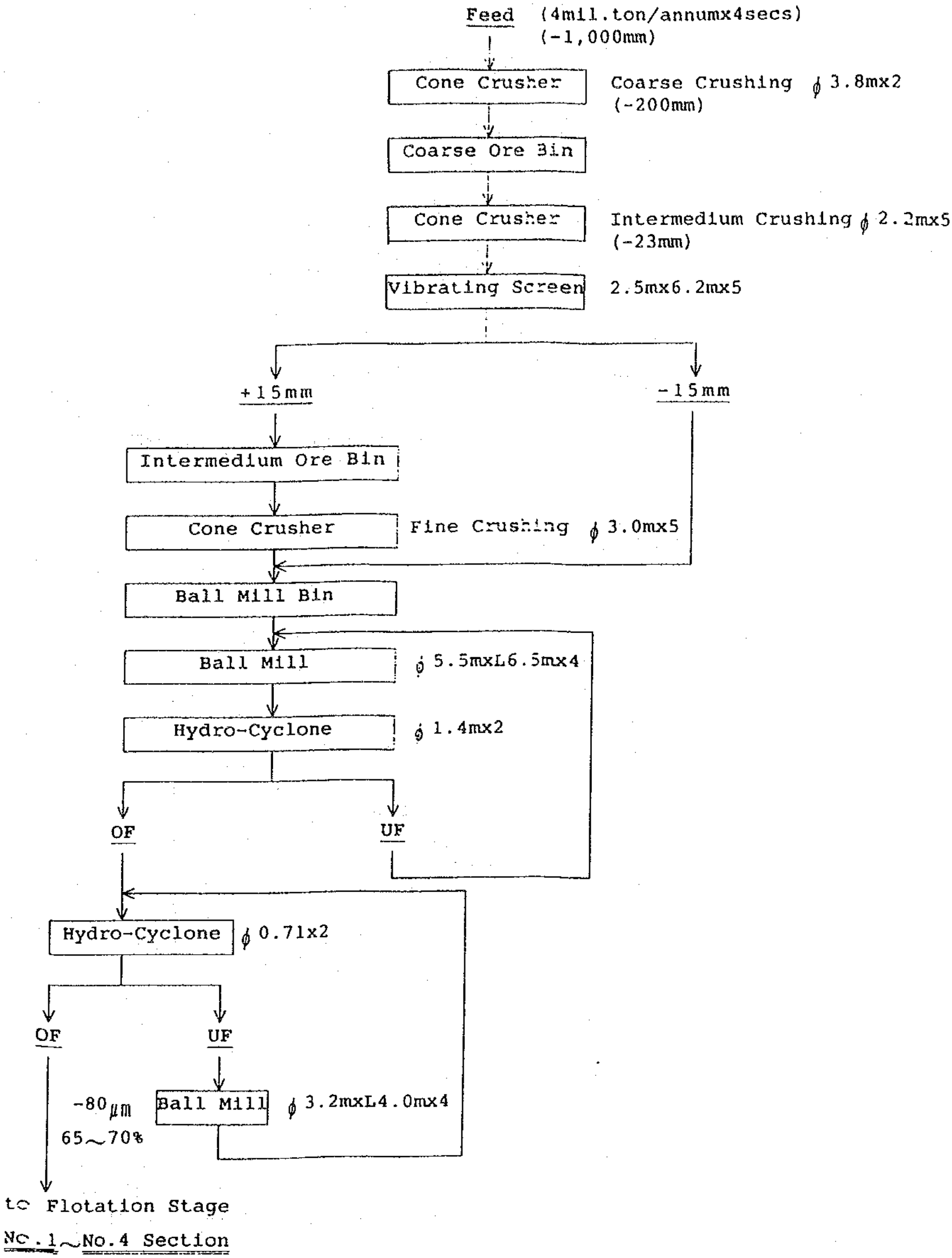


Fig -15 Flow Sheet of Crushing & Grinding Stage of No.1 ～No.4 Section

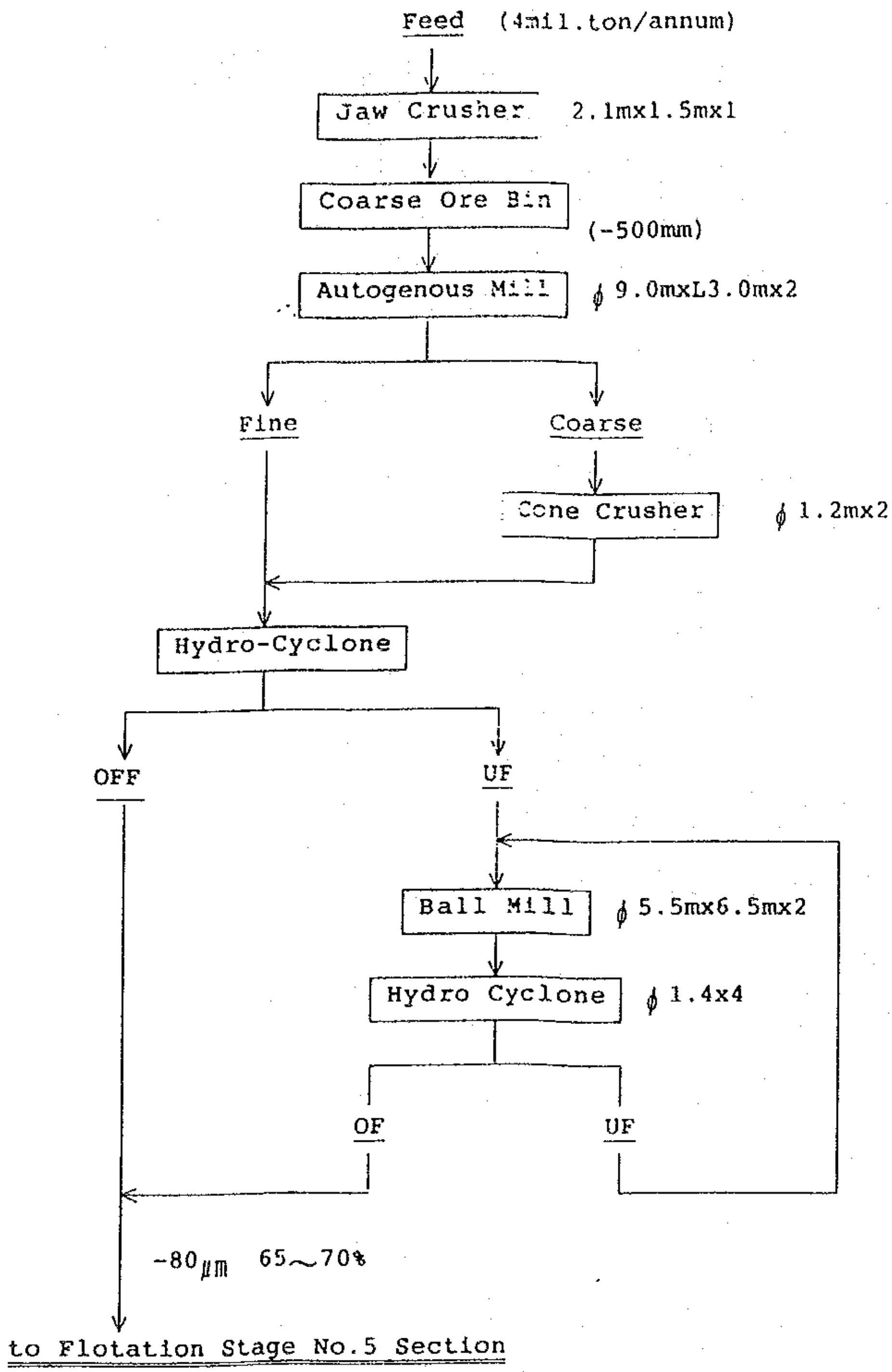


Fig -16 Flow Sheet of Crushing & Grinding Stage of No.5 Section

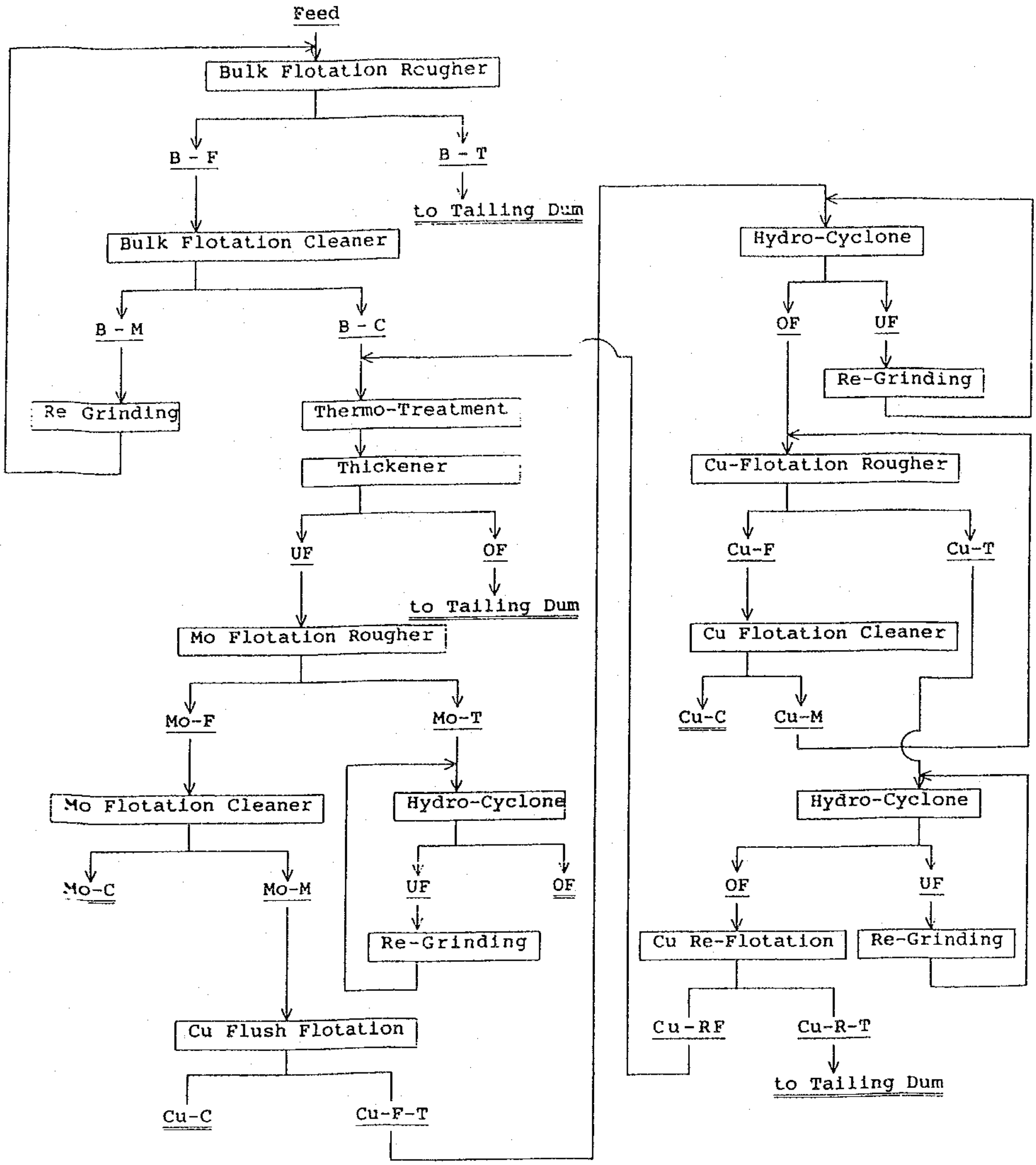


Fig -17 Flow Sheet of Mo/Cu Separation Flotation
Stage of No.1～No.5 Section

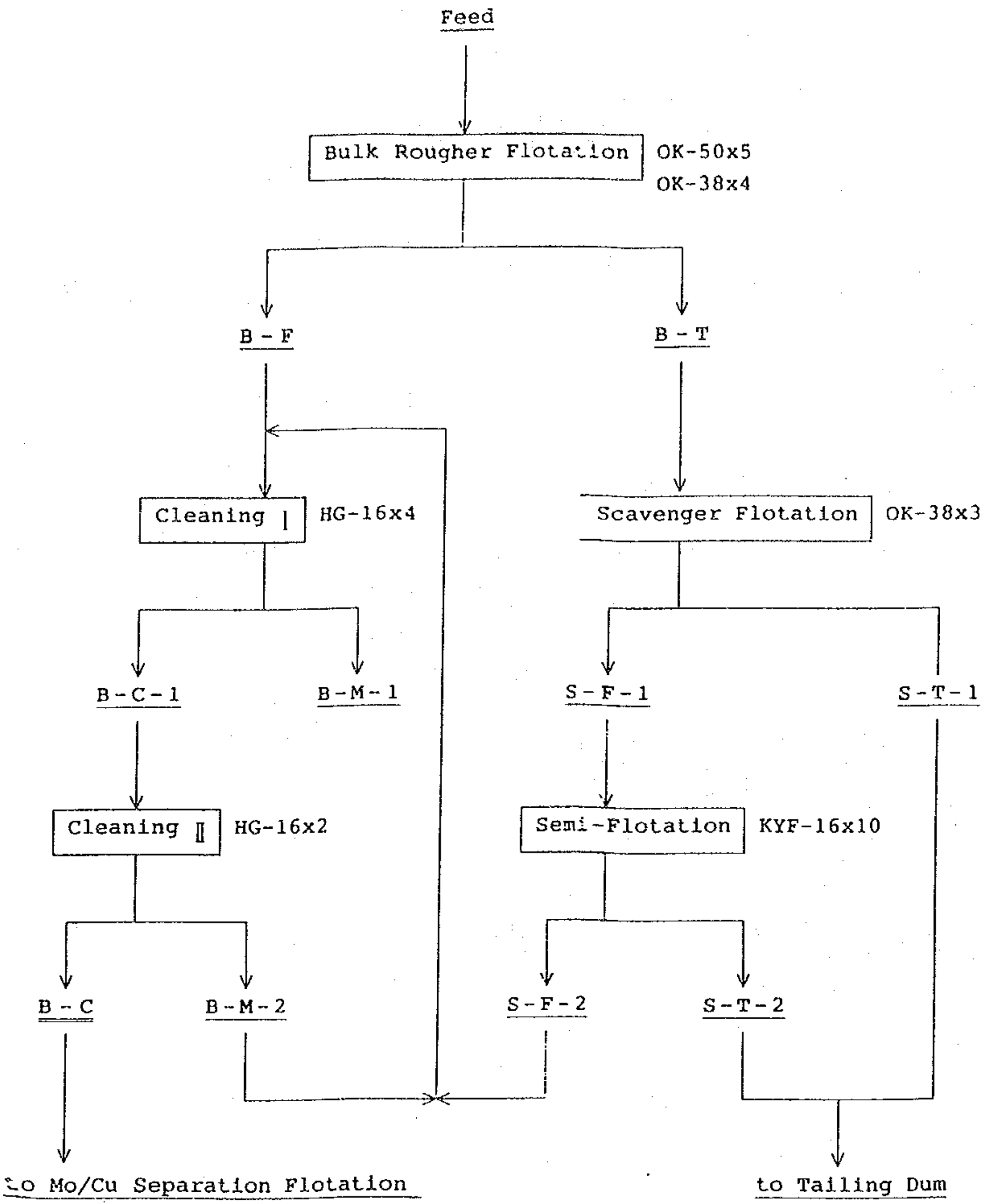


Fig -18 Flow Sheet Plan of No.6 Section

③ Dehydration and Drying

Both copper concentrate and molybdenum concentrate are dehydrated with disk filters. In winter, to reduce their water content to below 10% and thus prevent them from freezing, a further heat-drying process is carried out. To improve the process, in December 1992, one ceramic filter was introduced and is now being tested.

④ Waste Treatment and Water Recycling

The waste (tailing from the Mineral Processing Plant) flows gravitically to the tailing dam, which is approximately 6 km from the plant. In summer, tailing is discharged from the bank. In winter, however, since the channel surface freezes, tailing is released to the area surrounding the pond.

Overflow from the pond is sent passing through the culvert to the pump station installed in front of the bank. At the pump station, the overflow is mixed with dam seepage water and is pumped back for use in the plant. About 90% of water is reclaimed.

During the second site survey, we found that the seepage water was turbid. This is a seasonal phenomenon that results from thawing.

Figure 19 shows a vertical section of the pipeline from the mineral processing plant to the tailing dam.

Figure 20 shows the water balance of the recycling process water.

Figure 21 shows the mineral processing facilities layout.

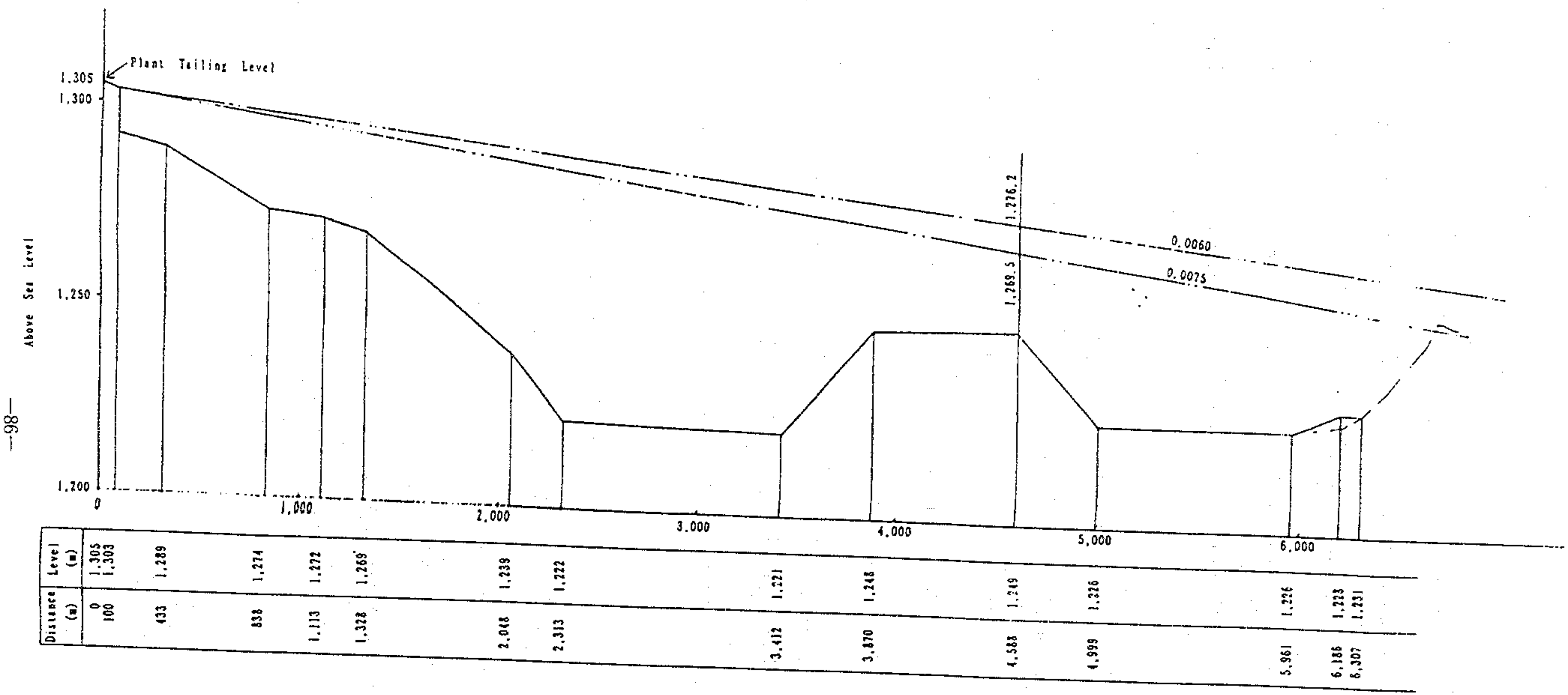


Fig -19 Tailing Pipe Line

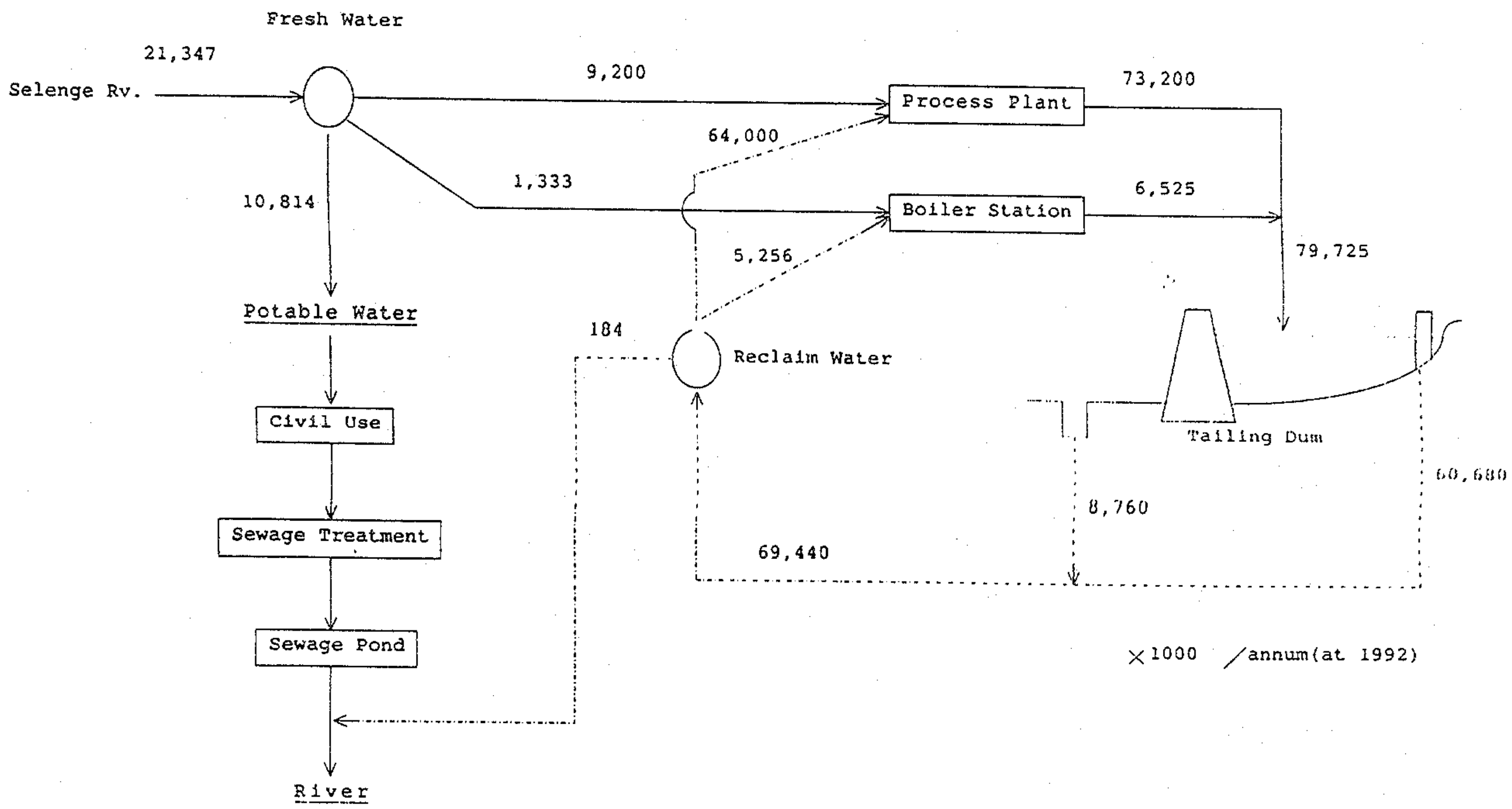


Fig -20 BALANCE Sheet of Reclaim Water

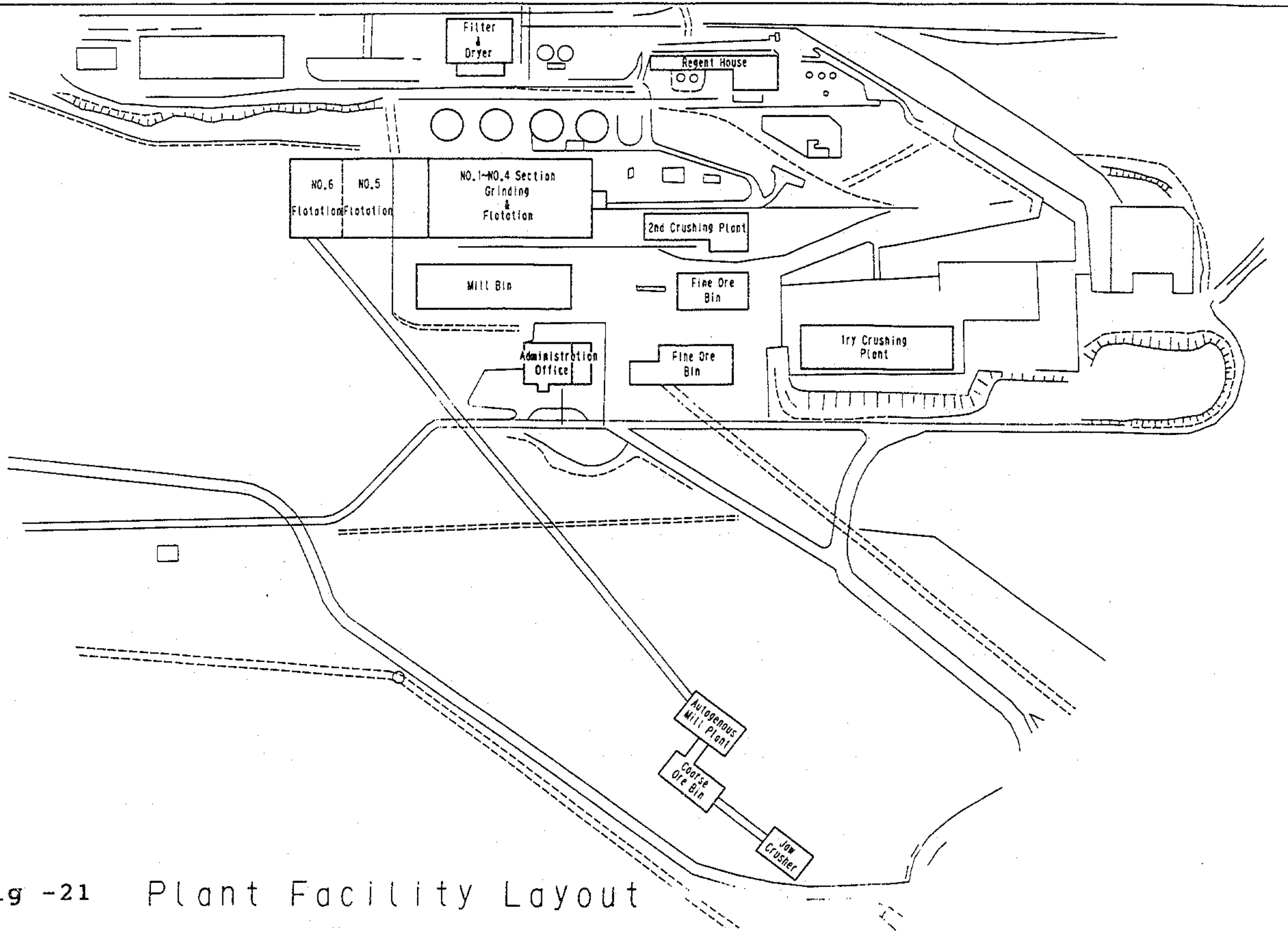


Fig -21 Plant Facility Layout

4-2-2 Production Control and Laboratory Research

(1) Production Control

①Operational results

As can be seen from Table 33, which shows the last 5 years' operation results, from 1990, when Unit No. 5 was completed, giving a total capacity of 20 million tons/year, these has been a large difference between budgeted and actual results. The difference was particularly large in 1991 when throughput budget attainment rate was only 70%. In 1992 the budget attainment rate recovered to 84% but was still short of 20 million tons.

Table 33 Mineral processing treatment results

Item	Unit	Classfication	1988	1989	1990	1991	1992
Throughput Q.11	×1,000 t/y	Budget Result	17,100 17,179	17,730 17,805	19,500 18,657	20,000 14,168	20,000 16,866
Feed Ore Grade Cu	%	Budget Result	0.866 0.866	0.861 0.863	0.787 0.826	0.772 0.83	0.767 0.791
Mo	%	Budget Result	0.0162 0.0162	0.0156 0.0171	0.0169 0.0218	0.0192 0.0219	0.0205 0.0199

Table 34 shows the flotation results for the last 5 years.

Table 34 Mineral processing results

Item	Unit	1988	1989	1990	1991	1992
Cu Concentrate weight	t	355,539	372,840	407,543	329,123	340,033
Cu Grade	%	34.22	32.38	30.41	29.98	30.05
Cu Recovery	%	81.78	80.49	80.94	76.41	78.33
Mo Concentrate weight	t	2,843	2,894	3,697	3,623	2,920
Mo Grade	%	54.03	54.65	53.50	51.84	52.00
Cu Grade	%	0.86	0.94	0.95	0.99	1.22
Mo Recovery	%	55.22	56.35	56.65	50.73	45.98
Tailing weight	t	16,821	17,428	18,243	13,864	16,515
Cu Grade	%	0.161	0.172	0.161	0.200	0.1684
Mo Grade	%	0.0058	0.0060	0.0078	0.0089	0.0093

The primary causes for the poor results in 1991 and 1992 were frequent power cuts arising form the electricity shortage, and a shortage of parts.

② Operations/Production Control

The throughput in mineral processing plant is measured continuously by two systems using conveyor scales to find the tonnage passing through the corn crushers at the crushing site, and the mill feed, and the data is compiled by computer.

To determine the results of the mineral processing, the grade of copper and molybdenum are automatically analyzed for the flotation feed, copper and molybdenum concentrates, and tailing. These values are also compiled as data.

The quantity of copper and molybdenum concentrate is measured as the number of vessels at the time of freight loading.

The above data, along with hourly integrated values, is displayed continuously on screens set up at strategic points.

In addition, important flow control factors such as mill slurry level, flotation level, pH and other data are continuously measured, incorporated as data by the computer and compiled with the above data for use in centralized operation control. The produced concentrates are weighed in iron pots (capacity approx. 1 ton) at the time of shipping. The grade of both copper and molybdenum concentrates are determined by analysis, in the analysis laboratory of the quality control section, of samples taken at the time when filled into pots.

(2) Operational Problems

① Long term problems

From a long term point of view, the problems the Erdenet mine will face in the future can be categorized to the following four items.

— Change of crude ore character

The main copper minerals in the crude ore will change from chalcocite (Cc, theoretical copper grade: 79.5%) and coveline (Cv, theoretical copper grade: 66.0%) to chalcopyrite (Cp, theoretical copper grade: 34.2%). The effect of this, together with the increasing pyrite (Py) and other gangue minerals, will considerably reduce the grade of copper concentrate.

Consequently, to maintain copper production levels it will be necessary to increase the tonnage of ore processing and to improve the copper recovery rate.

In the future, as the proportion of Cp in the crude ore increases, the mineral processing recovery rate will be greatly affected. The Cp/Cc ratio is expected to exceed 50/50 in 1995 and this will greatly affect the recovery rate.

— Improving the copper recovery rate

The copper minerals found in the secondary enrichment ore zones which are the object of current processing are the high flotability Cc and the comparatively low flotability Cv. The primary copper mineral, Cp, of which quantity will gradually increase from now on has a floatability between that of Cc and Cv. Bornite (Bn, theoretical copper grade 62.9 %), of which floatability is lower than that of Cp, is found in small quantity in the secondary enrichment ore, but, is negligibly small in the primary ore. Therefore as Cp is only copper mineral in primary ore, the processing results will become more stable than that of the secondary enrichment ore. Consequently, if an appropriate flotation condition was set out, inferred from examples of processing operations (Cp/Py separation) from porphyry copper mine of the world together with the experimental data and trial processing test carried out in Japan, which have to be confirmed by Erdenet, an improvement in recovery rate can be expected.

Looked at over the long term, because of the change in ore character from secondary enriched ore to primary ore the maintenance or improvement of results using the current mineral processing system cannot be counted on and measures must be taken in response to this.

— Concentrate copper grade decrease and arsenic grade

As mentioned above, change of copper minerals in the ore from mainly Cc, which has a high theoretical copper grade, to mainly Cp will, inevitably, entail a decrease in the concentrate grade. To keep this decrease as small as possible, we recommend that several tests be carried out on mineral processing reagents used by western countries to select suitable reagents for future Erdenet. The cause of high arsenic grade in feed ore is the presence of the arsenic-bearing copper mineral, tennantite. In flotation process, it is extremely difficult to separate the arsenic mineral from copper concentrate.

— Tailing pond capacity

The planned tailing pond capacity is 525,000,000m^3 and the volume of tailing deposited until 1992 was 186,000,000m^3. Consequently, the capacity remaining at the end of 1992 is assessed to be 338,900,000m^3 but, if the production was increased as mentioned in the later chapter , the pond will be filled by 2008. A new site must be investigated and plans to be started in good time.

② Short Term Problems

According to the results of this study, urgent problems in the mineral processing plant are as follows:

—Throughput budget shortfall.

This shortfall was particularly large in 1991 and 1992.

—No. 5 circuit's milling efficiency is inadequate.

—Stagnation of mineral processing results.

Low recovery of copper in copper concentrate, low copper grade, high arsenic grade and decrease in recovery rate from oxidized ore treatment etc. Each year the Erdenet mine processes, by flotation, approximately 2.5

million tons of "oxidized ore."

"Oxidized ore" is secondary enriched ore which has surface oxidation caused by additional weathering. The main minerals are chalcocite, coveline and chalcopyrite. "Oxidized ore" processing is problematic because, although the copper grade is high (approx. 0.8%), recovery is low (approx. 70 %) compared with secondary enriched ores.

For data on the above, refer to Table 35.

—Concentrate water content reduction problems

A part of concentrate is discharged from the kiln-type concentrate dryers into the air. This is an environmental pollution concern.

Energy costs for the dryers are high. (See Table 36.)

—Tailing treatment problems

When switching the tailing transportation method from gravity flow to pumping up, installation of new large slurry pumps (3,000kw × 3 sets for spare) (additional investment; already installed before the second study) is needed.

Additional operational cost is incurred in this regard. Electric power costs, in particular, will greatly increase. When there is a power cut, to prevent pipe blockage by deposited slurry, the latter is extracted and stored in the stockyard and post-recovery stockyard. To empty these stockyards in preparation for the next power cut a slurry pump is required.

Table -35 Oxide Ore Treatment Result

Item	Ore Discription	Year 1989	1990
Plant	Total	17,805	18,650
Throughput	Sulfide	13,543	15,420
(X1,000 t)	Oxide	4,262	3,230
Cu Grade	Total	0.86	0.83
in Feed Ore	Sulfide	0.83	0.80
(%)	Oxide	0.97	0.94
Cu Grade	Total	33.1	30.4
in Cu Conc.	Sulfide	32.9	30.5
(%)	Oxide	33.7	30.0
Cu Recovery	Total	80.5	80.9
in Cu Conc.	Sulfide	83.1	81.9
(%)	Oxide	73.6	76.7

Table -36 Energy Cost Rate for Thermal Treatment

mil. cal.

	1990	1991	1992
Steam for Thermal Treatment (A)	22,909	20,523	22,254
Hot Water for Heating (B)	883	-	2,800
Total ((C)=(A)+(B))	23,792	20,523	25,054
Steam Rate (A)/(C)x100 in Plant (%)	96.3	100.0	88.8
Erdenet Mine Total (D)	34,504	27,604	34,030
Steam Rate (A)/(D)x100 in Mine (%)	66.4	74.3	65.4

—Frequent of power cuts. Shortage of parts.

The effects of power cuts and parts' shortage are shown in Table 37 and Figure 22.

—Instrumentation equipment

The equipment installed for operations control — monitoring and data-sampling equipment and the ex-Soviet manufactured continuous on-line analysis apparatus and computer for compilation and logging of this data — is out-of-date and this, combined with its inadequate capacity, means that it is unsuitable for future modernization.

State-of-the-art online-update analysis apparatus is installed on circuit 5 alone and this as well as the above-mentioned ex-Soviet model are used merely for the compilation and monitoring of data, so there is still no process feedback or feed-forward and manual control is relied upon.

(3) The Mongolians' Plans

① Future Plans for Mineral Processing Operations

Plans up to 2010 have been prepared for the Mineral Processing Section. (See Table 38).

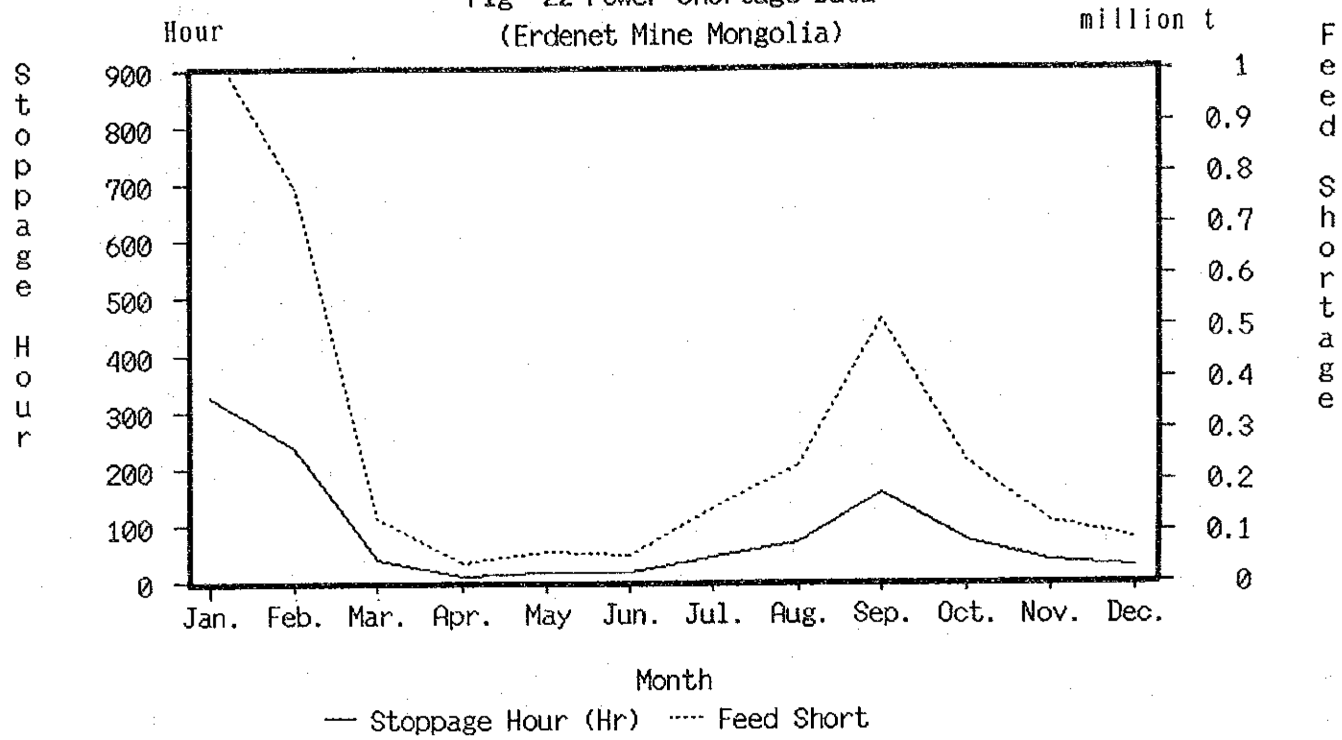
The basis of the long-term processing operation plan are measures to increase throughput to cope with the shift of ore from secondary enriched to primary and thus prevent a reduction in profits.

The increased throughput , as Table 38 shows, is planned to reach 26 million tons/year by 2010. In order to reach this target, No. 6 flotation circuit, with a 4 million tons/year capability, will be set up. Using this as a substitute circuit, it is planned that units 1 – 4 be modified (from 4 to 4.5

Table 37 Data on Electricity Shortage(1992)

	Suspended Time by Power Cut (Hour)	Decrease of Throughput (1,000 ton)	Decrease of Cu Conc. (ton)	Decrease of Mo Conc. (ton)
Jan.	326	953	8,458	84.0
Feb.	237	694	6,658	65.1
Mar.	39	114	1,017	10.6
Apr.	12	34	102	2.8
May	18	52	554	4.9
Jun.	16	48	495	5.1
Jul.	44	129	1,460	12.3
Aug.	71	206	556	14.7
Sept.	157	460	1,294	40.2
Oct.	73	212	568	23.2
Nov.	36	105	1,015	11.5
Dec.	26	76	734	7.4
Total(A)	1,055	3,085	22,911	281.8
Note:				
Results(B)		16,866	347,754	2,920
Plan(C)		20,000	442,669	4,400
(D)=(C)-(B)		3,134	94,914	1,480
(A)/(D) (%)		98.4	24.1	19.0

Fig -22 Power Shortage Data
(Erdenet Mine Mongolia)



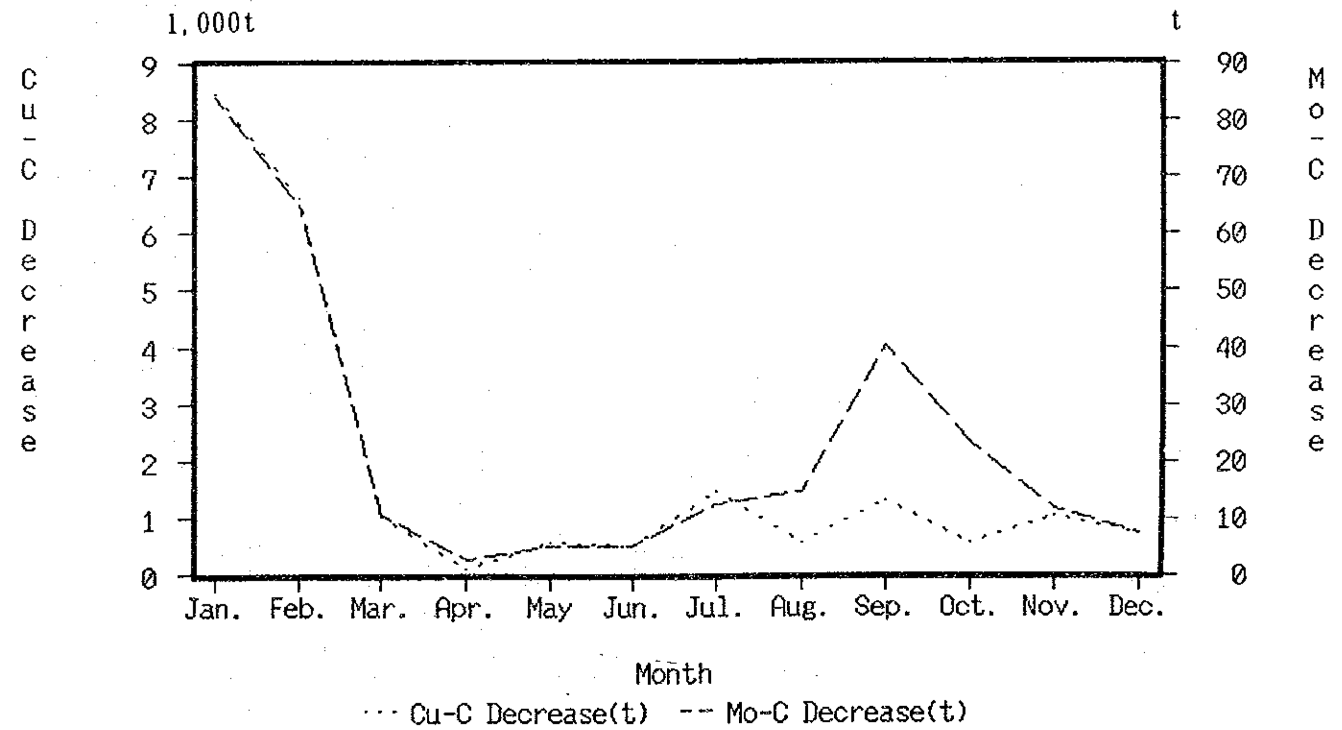


Table 38 Long-term Production Plan
(Elaborated by Erdenet Mine)

Item	Unit	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Thoughput	thous t	20,500	20,500	21,000	22,000	22,500	22,500	22,500	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	26,000	26,000	26,000
Cu feed grade	%	0.70	0.72	0.70	0.67	0.66	0.66	0.64	0.57	0.57	0.57	0.57	0.52	0.52	0.52	0.52	0.49	0.49	0.49
Mo feed grade	%	0.0177	0.0169	0.0155	0.0149	0.0149	0.0149	0.0142	0.0142	0.0142	0.0142	0.0141	0.0141	0.0141	0.0141	0.0141	0.0128	0.0128	0.0128
Cu Metal in Ore	thous t	142.5	148.0	148.0	148.0	148.0	148.0	144.0	142.0	142.0	142.0	142.0	130.0	130.0	130.0	130.0	127.0	127.0	127.0
Mo Metal in Ore	t	3,464	3,464	3,250	3,280	3,350	3,350	3,200	3,550	3,550	3,550	3,530	3,530	3,530	3,530	3,530	3,330	3,330	3,330
Cu Recovery	%	79.3	80.5	80.5	80.5	80.5	80.5	80.9	81.3	81.3	81.3	81.3	81.65	81.65	81.65	81.65	82.0	82.0	82.0
Mo Recovery	%	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	48.0	48.0	48.0	48.0	48.0	48.0	48.0	48.0
Cu Metal in Conc.	thous t	113.3	120.0	120.0	120.0	120.0	120.0	117.0	115.5	115.5	115.5	115.5	106.1	106.1	106.1	106.1	104.1	104.1	104.1
Mo Metal in Conc.	t	1,732	1,732	1,625	1,640	1,675	1,675	1,600	1,775	1,775	1,775	1,690	1,690	1,690	1,690	1,690	1,600	1,600	1,600
Cu Conc. Cu grade	%	28.2	30	29.65	27.2	27.2	27.2	27.2	23.47	23.47	23.47	23.47	21.8	21.8	21.8	21.8	20.8	20.8	20.8
Mo Conc. Mo grade	%	50	45	45	45	45	45	45	45	45	45	40	40	40	40	40	40	40	40
Cu Conc. weight	thous t	400,103	400,000	404,722	441,176	441,176	441,176	430,147	492,118	492,118	492,118	492,118	486,697	486,697	486,697	486,697	500,481	500,481	500,481
Mo Conc. weight	t	3,464	3,049	3,611	3,645	3,722	3,722	3,555	3,945	3,945	3,945	4,225	4,225	4,225	4,225	4,225	4,000	4,000	4,000

million tons/year) successively without a decrease in throughput. If implemented, the treatment of 26 million tons/year (4.5 million tons/unit/year ×4 + 4 million tons/unit/year ×2) will be possible.

② Tailing Transportation System and Tailing Pond Augmentation

The elevation of the tailing pond is approximately 1260m, 43m lower than that of the mill tailing exit (1303m). As the distance between the plant and the tailing dam is 6.4km, the incline is 0.0067 . The incline needed for the mill tailing of Erdenet Mine to run down gravitically is approximately 0.006 (this requires head difference of 39 m for a distance of 1264 m), and the gravity flow will discontinue within one or two years. Therefore, an Antlia was installed on the left side of the embankment for pumping the slurry, three 3,000kw slurry pumps have already been installed, and tailing transportation to the pond side will start from the end of 1993. The transportation system is now being adjusted toward this plan.

Figure 23 shows the pump-up circuit for tailing.

(4) Laboratory Test and Research

① Organization · Personnel

Test and research in connection with mineral processing are conducted by the Central Research Laboratory, a subdivision of the Production Technology Department. However, work related to chemical analysis, pollution measurement and analysis, and occupational health, is not included in the laboratory's responsibilities, it is handled by other organizations (chemical analysis laboratory, etc.).

The Central Research Laboratory is broadly divided into two groups:

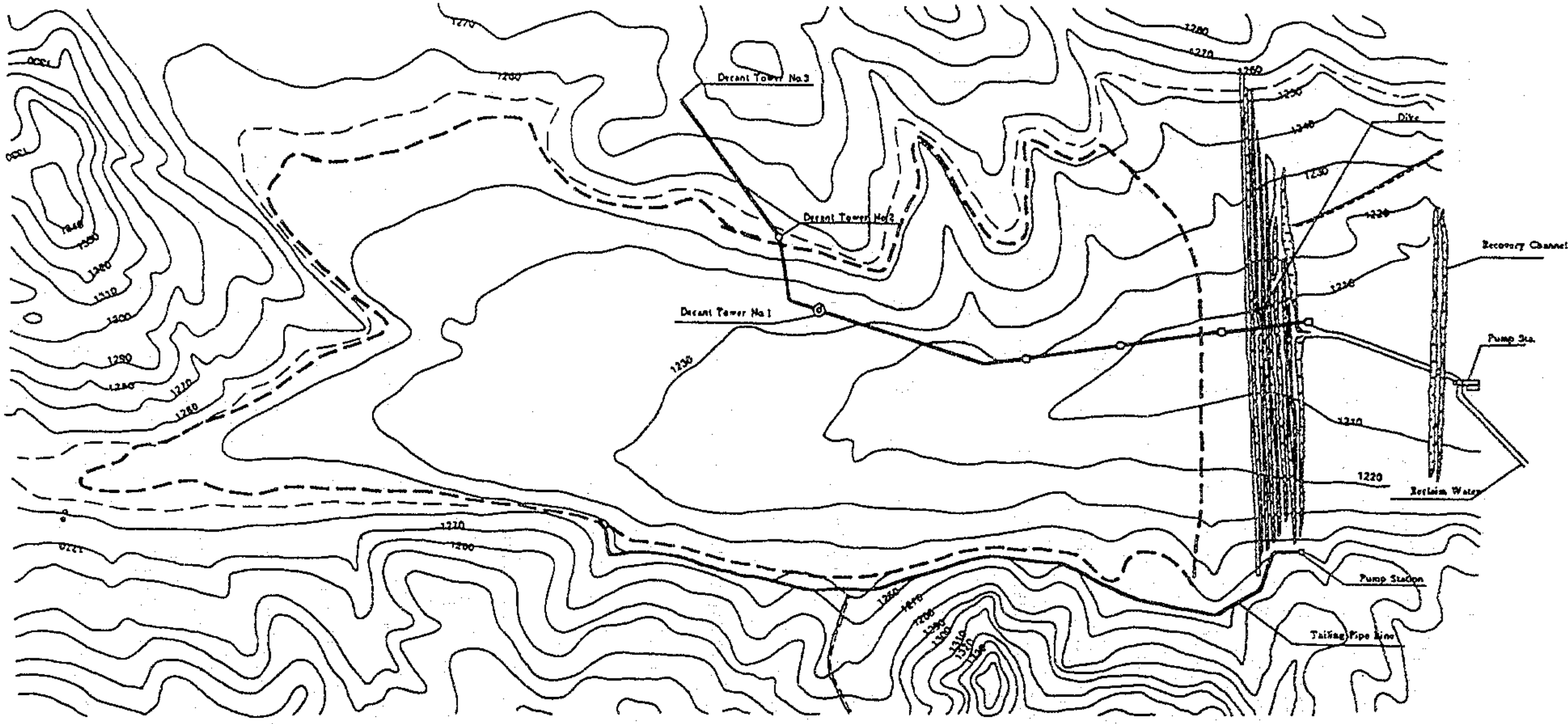
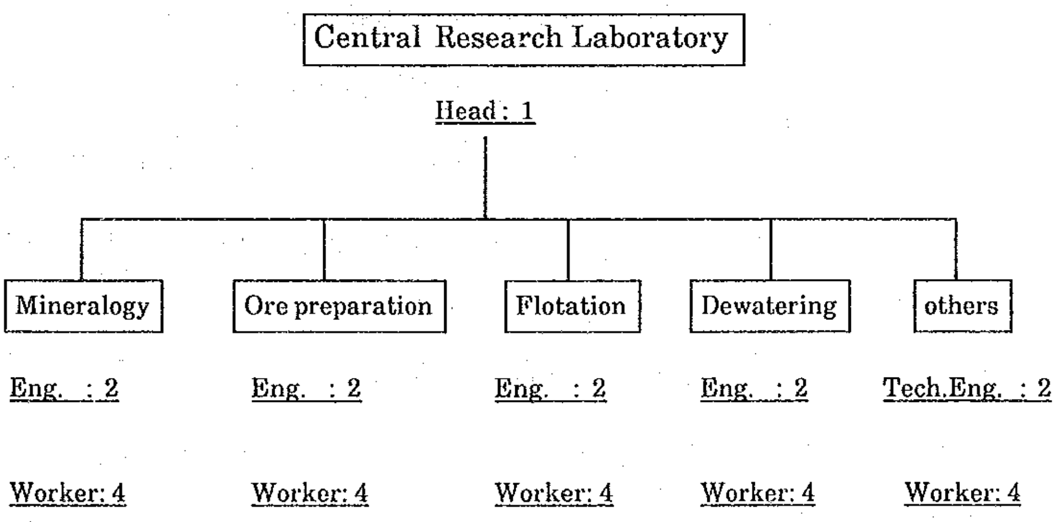


Fig 23 Planned Tailing Pipe Line

one is the mineral study group and the other is the mineral processing research group. The latter is composed of three sections divided according to their responsibilities: test sample preparing, bulk separation flotation and dewatering - drying.

The laboratory consists of 24 personnel: 1 section chief, 7 reseachers (engineers), 1 associate reseacher (technical engineer) and 15 assistant workers. All research personnel have at least a university undergraduate education, and as in other sections, most of them have experience of study abroad in the former USSR or Eastern Europe. As a result, their second language is generally Russian and research reports are written in Russian. There are few researchers who can speak English.

The above-described section classifications are shown below.



Engineer training is very much encouraged. This year one engineer is returning from the U. S. having finished his studies and it is planned to send another to Japan to study.

② Research Field and Equipment

— Mineralogical Study Equipment

For mineralogical study, the optical microscope is the main apparatus used, and rock cutter, polishing machines, etc. are used for the pretreatment (preparation of polished briquette of ore and thin section of rock) following the microscopic observations.

This equipment is itemized below:

Equipment	Model	Size	Quantity	Installation
Microscope POLAM	P-312	—	1	1978
Microscope POLAM	P-312	—	1	1978
Microscope	MBS-9	—	1	1978
Cutting machine	—	ϕ =230mm	1	1978
Polishing machine	—	—	3	1978

The microscopes are Russian-made polarized light microscopes and include reflecting light metal microscopes and transmitted light rock microscopes. However, the performance of the object lenses, which are crucial to the microscope, are inferior to lenses used at present in Japan. There is no microscopic photography equipment and the structure of each mineral sample viewed under the microscope is sketched.

The rock cutters and polishing machines are home-made and are not sufficiently accurate. Production of good quality polished briquette with a smooth surface is difficult because the equipment is hand-operated.

Russian-made resin (epoxy-based) is used as a polishing briquette, and alumina and oxidized chrome (also Russian-made) are used as polishing agents. The quality of these is far inferior to that of Japanese products and, moreover, the use of only 1 type of resin is extremely inconvenient for the preparation of polished briquette. At the Erdenet mine, currently the procurement of even the above materials is difficult and, for the time being, inventory-on-hand (1 - 2 years) is being relied upon. Moreover, as the inventory is in normal temperature storage (a cool, dark place would be better), the deterioration of some items is occuring.

— Mineral Processing Research Equipment

The equipment and materials relating to mineral processing research are shown in Table 39.

Compared to the above-described mineralogical study equipment, the types, quantity and grade of the equipment and materials are good. However, most of the equipment is old and was installed when the mine started operating in 1978, and there are very few materials which have been purchased in the last 10 years. As a result, the machinery and equipment are out of date and obsolescent, and if a transition is made with no change in that situation, there will be the possibility that various problems relating to Central Laboratory efficiency, the accuracy of the data, testing precision, and the maintenance of safety in laboratory works might arise in the future.

Table 39: Central Laboratory Equipment·Machinery List

Equipment/	Model	Capacity	Quantity	Installation Date
[Semi Industrial Inst.]				
Ball mill	900*900	0.5 t/h	1	1978
Classifier	—	0.5 t/h	1	1978
Crusher	CM—165A	1.0 t/h	1	1978
Grizzly	93—YS	0.25 t/h	1	1978
Fine ball mill	—	0.5 t/h	1	1978
Reactants Feeder	158a-PT	—	10	1978
Flotation cell	FML-25	25	4	1978
Flotation cell	FML-12.5	12	4	1979
Thickener	306-SG	—	2	1978
Vacuum pump	VN-461M	—	2	1978
Pump	NP-1M	—	1	1979
Vertical pump	—	—	4	1983
Classifier	47 kg.	—	1	1979
Vaporization glasses	—	100	3	1983
Filter system	30 FTV	—	1	1978
[Lab. equipment]				
Mill	ML-40	—	4	1979
Flotation cells	FM-1M	1	2	1990
	FM-2M	3	2	1990
	FM-189	0.125-0.5	5	1980 1990
	237-FLA	3	5	1986 1990
	240-FLA	1	8	1986
Ion meter	EV 74	—	1	1984
Milivolt meter	pH-121	—	3	
Automatic titler	VAT-13	—	1	1983
Size analysis sieves	236B-6R	—	3	1979 1985
Vibrating mill	756-DRM	—	3	1978
Washing disk	ADA-175	—	2	1979

— Fields of Studies and Research

Studies and research are implemented on the basis of an annual research schedule according to the two groups (mineralogical and mineral processing) described above, and have the following objectives:

—to research the state of existence of mineral ores.

—to review and improve the present operating conditions.

—to improve of the equipment for mineral processing based on present and future plans.

—to develop new technology.

—to provide technical support and man power support at the operations site.

To determine research themes, first, suggestions are received from the production technology department manager and the mineral processing section chief, and a research plan is drafted in the research section. Next, the 3 people discussed on the draft and submit the result to the vice-president (in charge of technology). The vice-president, after review, gives it final approval.

The number of research projects, both large and small, is approximately 20 to 30 per year.

— Features of Mineralogical Study

The greater part of the research is for the purpose of grasping the mineral composition of test samples of the minerals that are presently being mined. In other words, research centers on the so-called mode analysis method of testing and analysis of mineral composition. The results become the basic data for the various conditions for mineral processing treatment (preparation of test samples, crushing and flotation characteristics) and contribute to the stability and improvement of the mineral processing operations.

The special feature of this study is that first the supplied test samples undergo flotation treatment under the same conditions as found on site and mode analysis is implemented on the polished briquette created from the recovered froth.

There are approximately 200 to 450 test samples each year, but it is judged that comparatively good studies are being executed considering the present personnel and equipment.

However, the above-mentioned mineral composition analysis requires a high degree of specialist knowledge and many years of experience. The current mineralogical researcher is competent and there is no problem, but the training of a replacement (newly-employed female graduate) is lagging and it will probably be some years before she reaches the level of the current research personnel. Thus, in the future, it will be necessary to automate mineral composition analysis through the use of image analysis apparatus.

— Mineral Processing Research

Although it is aging, the laboratory possesses the basic research equipment and is performing a broad range of studies ranging from small-scale tests in the laboratory to continuous flow tests on an operational scale, depending on the research theme. As to content, studies to provide technical assistance and improvements to plant operations are overwhelmingly numerous and a large contribution is made to the maintenance and augmentation of operational results but there is comparatively little research for the development of new technology.

Technical information gathering was relied largely on the Russian-speaking zone which formed the core of the former Soviet Union.

As a result, information on mining technology and industry conditions is extremely limited compared with that in western countries. Particularly remarkable is the lack of information on items which directly affect research results, namely: data on the latest chemical reagents and information on test equipment and machines and all types of instrument.

③ Testing and Research in Japan

In order to gain an insight into the problems at the Erdenet mine, samples taken at the time of the site survey were brought back to Japan and mineralogical studies and mineral processing tests were carried out on them. The details are given in the appended mineralogical studies and mineral processing tests reports.

— Mineralogical studies results

Data on the main minerals in the Erdenet deposit has been prepared. Consequently, in Japan, qualitative and quantitative studies on the naturally occurring arsenic in the ore were carried since such studies were difficult to execute at Erdenet.

— Arsenic minerals in the ore

- The main arsenic mineral consists of tennantite ($(Cu, Fe)_{13} As_4 S_{13}$) and traces of enargite ($Cu_3 As S_4$)can also be observed.

- Tennantite can be observed in both the primary and secondary enriched ores but shows a tendency to be irregularly and unevenly distributed.

- Particle size of tennantite is in mainly distributed in the range 0.0 1–0.1mm but comparatively fine grains (of the order of tens of μm) frequently appear.

- Tennantite often exists together with chalcopyrite and, as well as being spotted in the gangue mineral it forms tine vein in the pyrite. In addition, coexistent bornite and chalcocite can also be observed, although in small quantities.

- The copper concentrate contains approximately 1–2 % tennantite.

— The results of EPMA quantitative analysis of main mineral ores — especially arsenic content. Copper and arsenic content are shown in Table 40.

Table 40: Results of EPMA Analysis

Tennantite : $(Cu, Fe)_{12} As_4 S_{13}$

Analysis No.	Cu	Fe	As
1	39.59	2.01	15.02
2	39.69	2.52	13.64
3	40.09	7.56	17.86
4	39.99	7.42	17.85
5	40.45	3.88	19.08
6	40.25	5.16	13.38
7	37.63	3.48	10.95
8	38.03	2.04	12.65

Chalcopyrite : $CuFeS_2$

Analysis No.	Cu	Fe	As
1	33.99	30.10	tr
2	34.29	29.92	tr
3	34.94	30.33	0.01
4	34.17	30.38	0.01
5	34.62	30.17	tr
6	34.62	30.35	tr

Bornite : $Cu_5 FeS_4$

Analysis No.	Cu	Fe	As
1	62.80	10.89	0.03
2	62.92	11.09	0.01
3	62.49	11.19	0.03
4	62.79	11.11	tr

Chalcocite : Cu_2S

Analysis No.	Cu	Fe	As
1	76.15	0.76	0.01
2	76.09	0.90	0.01
3	78.05	0.50	0.01
4	78.43	0.59	tr
5	76.90	0.42	tr
6	77.73	0.49	0.01

Covelite : CuS

Analysis No.	Cu	Fe	As
1	66.87	0.65	tr
2	66.42	0.66	0.02
3	66.33	0.71	0.02
4	66.34	0.71	0.02
5	67.08	0.75	0.01
6	67.28	0.54	0.02

Pyrite : FeS_2

Analysis No.	Cu	Fe	As
1	tr	47.03	tr
2	tr	46.85	tr
3	tr	46.77	0.01
4	tr	46.90	tr
5	tr	46.76	0.01
6	tr	46.88	tr
7	tr	46.72	tr
8	0.01	46.92	0.03

The following points are clarified by the EPMA analyses:

- Antimony rich mineral facies can be seen in one part of the tennantite, but the arsenic content of the said mineral is approximately 11–19 % by weight (Average for 8 data = 16 %).

- The arsenic content of the other ore minerals is extremely small (less than 0.03 % by weight). In particular, the arsenic content of chalcopyrite, which is the main concentrate constituent, is no more than a trace (less than 0.01% by weight).

  Furthermore, the only independent arsenic mineral observed was a microscopic trace of arsenopyrite.

- The ratio of tennantite to chalcopyrite/bornite is roughly not more than 1/100 but, on the other hand, the ratio of tennantite arsenic content to chalcopyrite/bornite arsenic content is greater than 10,000/1.

- Accordingly, the majority of the concentrate arsenic content can be thought of as initiating from the intermixed tennantite (for example, if 1% tennantite is mixed into the copper concentrate, the concentrate arsenic grade increases by 0.16 %). In short, reduction of the concentrate arsenic grade becomes a question of how to control the quantity of tennantite included.

— Arsenic Distribution in the Orebody

The separation by flotation of chacopyrite and tennantite, which is the main source of arsenic in the concentrate, is difficult because the two minerals have similar flotation characteristics. Accordingly, in order to grasp prior knowledge of how arsenic (tennantite) is distributed in the orebody so that tennantite content can be controlled at the mining stage, a preliminary geochemical analysis (multi-constituent analysis of ore sample) was performed.

After discussion with the mine geologist, in order to gain an understanding of the horizontal and vertical distribution of arsenic in the deposits, targeting both primary and secondary enriched ores, 82 samples from past drilling core were picked.

The total number of elements in the analysis, including trace constituents as well as copper and arsenic, was 13. The results of the analysis are shown in Table 41.

- The arsenic analysis results for the 82 samples show:

  Max. 720 ppm, Min. 2 ppm and Ave. 36 ppm with a standard deviation of 118.5 ppm.

  Briefly, the arsenic is not distributed homogeneously in the deposit, but irregularly, showing a large difference between maximum and minimum values.

- The results of an analysis for both ore quality groups are shown in the following table:

Ore Quality	Number of Samples	Maximum Value	Minimum Value	Average Value	Standard Deviation
Primary	65	660	2	29	93.3
Secondary Enriched	17	720	2	64	180.6
Total	82			(36)	(117.7)

The results of the statistical calculations indicate that the arsenic grade of secondary enriched ore is high while that of primary ore is low and it

Table 41 Results of Geochemical Analysis

Section	No of DDH	Level (m)	depth (m)	sea level (m)	Sample No.	Au ppb	Ag ppm	As ppm	Bi ppm	Cu ppm	Cd ppm	Hg ppb	Mo ppm	Pb ppm	Sb ppm	Se ppm	Zn ppm	Te ppm
A－A	10116	1402.81	121.0-123.3	1281.81-1279.51	H01	<1	1.3	2	0.3	1900	1.8	10	160	19	0.2	0.2	430	0.2
A－A	10059	1464.88	180.3-181.2	1284.58-1283.68	H02	<1	1.1	330	<0.1	7000	1.0	130	128	130	110.0	1.6	225	0.7
A－A	10104	1505.00	225.2-226.9	1279.80-1278.10	H03	<1	1.6	2	0.1	3500	0.7	20	160	40	1.2	0.8	203	0.1
A－A	10043	1534.88	259.6-263.6	1275.28-1271.28	H04	<1	0.2	10	<0.1	620	1.3	30	5	11	0.8	<0.2	214	0.2
A－A	10034	1475.78	195.4-197.6	1280.38-1278.18	H05	<1	1.3	2	<0.1	4000	<0.1	10	128	5	0.2	1.0	155	0.2
A－A	10026	1506.30	238.4-241.0	1267.90-1265.30	H06	<1	0.6	4	0.1	1000	0.2	10	4	28	0.4	0.6	148	0.2
A－A	10125	1444.63	163.3-164.4	1281.33-1280.23	H07	<1	1.2	2	<0.1	4800	<0.1	20	71	6	0.6	1.2	49	0.3
A－A	10018	1477.19	195.0-197.5	1282.19-1279.69	H08	<1	5.0	720	1.5	6600	1.5	280	92	114	130	2.2	358	1.5
A－A	10083	1445.74	165.0-167.0	1280.74-1278.74	H09	<1	2.0	104	0.9	4200	1.2	50	210	122	14.0	1.8	317	0.3
A－A	10013	1460.61	178.0-180.5	1282.61-1280.11	H10	<1	2.0	46	1.2	4300	0.9	40	137	50	9.6	0.8	215	0.3
A－A	10135	1430.30	148.6-150.1	1281.70-1280.20	H11	<1	2.0	2	1.0	4300	0.5	30	180	14	0.2	0.8	138	0.1
A－A	10006	1458.99	177.2-180.0	1281.79-1278.99	H12	3	2.2	98	2.3	4000	2.2	40	345	167	20	2.2	630	0.2
XII	10101	1446.23	164.2-166-3	1282.03-1279.93	H13	<1	1.0	2	1.2	2000	0.3	20	18	55	1.4	1.0	127	0.4
XII	10048	1468.05	186.4-189.1	1281.65-1279.95	H14	<1	1.4	2	1.6	4100	0.8	10	32	20	2.8	0.6	117	0.7
XII	10047	1489.30	208.6-210.5	1280.70-1278.8	H15	2	2.8	2	0.3	6200	1.1	20	29	13	3.0	0.6	135	0.2
XII	10046	1512.28	231.2-233.5	1281.08-1278.78	H16	<1	1.1	2	3.9	820	4.6	10	9	162	1.2	0.4	1020	0.5
XII	10045	1522.43	241.6-243.0	1280.83-1279.43	H17	<1	1.5	10	0.6	2600	0.2	30	71	19	0.6	0.4	290	0.3
XII	10044	1505.08	223.9-225.9	1281.18-1279.18	H18	<1	1.0	2	0.3	1700	1.1	10	22	9	0.8	0.4	173	0.1
XII	10039	1484.38	186.0-188.5	1298.38-1295.88	H19	<1	0.9	2	0.2	1600	0.3	20	71	11	0.4	0.6	130	0.3
XII	10040	1421.57	143.1-144.7	1278.47-1276.87	H20	<1	1.0	2	0.1	1700	0.5	20	45	43	<0.2	0.4	115	0.2
XII	10075	1413.81	130.0-132.7	1283.81-1281.11	H21	<1	0.9	2	<0.1	2200	3.5	10	120	13	<0.2	<0.2	135	<0.1
IV	10031	1470.63	188.9-192.0	1281.73-1278.63	H22	<1	0.8	4	<0.1	1800	0.2	20	18	15	0.4	<0.2	63	<0.1
IV	10030	1496.32	2140.-216.0	1282.32-1280.32	H23	<1	0.6	4	<0.1	1100	0.3	20	8	4	0.4	<0.2	33	0.1
IV	10029	1489.31	208.7-211.3	1280.61-1285.02	H24	<1	1.1	4	<0.1	2900	0.1	10	60	6	0.4	0.4	33	0.1
IV	10027	1476.15	195.5-197.5	1280.65-1278.65	H25	<1	2.8	8	<0.1	>10000	<0.1	20	72	4	0.8	0.6	35	<0.1
IV	10025	1474.69	194.5-197.5	1280.19-1277.19	H26	<1	1.2	2	<0.1	3400	0.2	20	80	18	0.4	0.8	73	<0.1
IV	10024	1493.01	207.8-210.2	1276.61-1282.81	H27	<1	0.8	10	0.2	1600	0.2	10	195	12	2.2	0.6	53	0.1
IV	10022	1500.95	216.4-218.4	1284.55-1282.55	H28	<1	1.8	2	0.2	4000	1.3	10	248	40	<0.2	0.4	338	<0.1
IV	10078	1476.35	194.8-196.8	1281.55-1279.55	H29	1	2.8	2	0.8	7800	1.2	20	180	21	0.6	0.6	339	<0.1
IV	10080	1435.00	158.0-160.0	1277.00-1275.00	H30	3	0.8	4	<0.1	1600	0.2	10	108	10	<0.2	0.2	94	<0.1
I	10023	1488.57	206.5-268.5	1282.07-1220.07	H31	<1	0.6	6	0.1	450	0.2	10	1	9	0.4	<0.2	36	0.1
I	10021	1476.24	194.6-196.9	1281.64-1279.34	H32	<1	0.5	4	0.1	880	0.4	10	14	12	<0.2	0.2	136	<0.1
I	10019	1475.97	192.6-194.9	1283.37-1281.07	H33	<1	2.3	134	0.3	7900	0.7	50	75	38	33	1.4	95	0.3
I	10084	1444.85	190.1-192.6	1254.75-1252.25	H34	<1	2.4	118	0.7	3600	1.1	100	66	115	56	1.4	275	0.3
I	10016	1444.61	162.2-164.2	1282.41-1280.41	H35	<1	1.8	48	0.7	4600	<0.1	90	257	8	4.2	1.4	41	0.1
I	10015	1461.47	179.2-181.0	1282.27-1280.47	H36	<1	0.8	4	0.2	1300	<0.1	30	16	6	0.2	0.4	46	0.1
I	10066	1437.40	155.4-157.3	1282.00-1280.1	H37	4	1.4	2	0.3	1200	<0.1	10	3	35	<0.2	<0.2	85	<0.1
V	10070	1459.09	178.8-180.9	1280.29-1278.19	H38	<1	1.3	20	0.1	4200	0.8	30	54	27	4.2	1.2	240	0.1
V	10014	1460.08	179.5-182.0	1280.58-1278.08	H39	<1	1.6	20	0.1	4900	0.6	20	180	70	5.6	0.6	185	0.1
V	10012	1445.44	165.0-167.8	1280.44-1277.64	H40	<1	2.8	132	2.6	5500	0.3	40	268	13	6.0	1.2	66	0.1
V	10011	1460.93	182.0-184.0	1278.93-1276.93	H41	<1	2.7	324	2.4	5500	1.7	80	233	2	4.0	1.2	22	0.2
V	10010	1444.34	163.5-165.5	1280.84-1278.84	H42	<1	3.2	6	3.1	5700	<0.1	40	168	12	2.0	2.0	115	0.1
A－A	10013	1460.61	157.9	1302.71	V01	10	3.0	660	0.2	3150	1.3	150	39	99	120	0.8	340	0.8
A－A	10013	1460.61	163.9	1296.71	V02	<1	1.2	4	0.1	3150	<0.1	20	24	3	0.6	1.0	17	0.1
A－A	10013	1460.61	217.3	1243.31	V03	<1	1.0	4	<0.1	3750	1.2	20	130	16	0.8	0.6	276	<0.1
A－A	10013	1460.61	239.5	1221.11	V04	<1	1.0	4	0.3	3300	0.5	20	43	23	<0.2	0.6	118	<0.1
A－A	10104	1505.00	186.0-190.0	1319.00-1315.00	V05	1	0.3	2	0.1	1050	<0.1	10	9	6	0.4	0.4	114	<0.1
A－A	10104	1505.00	224.0-226.0	1278.00-1279.00	V06	1	2.3	2	5.0	4450	0.1	10	55	12	2.0	<0.2	122	0.1
A－A	10104	1505.00	250.0-252.0	1255.00-1253.00	V07	4	1.2	2	0.5	1670	0.4	10	18	4	<0.2	0.6	215	<0.1
A－A	10104	1505.00	274.0-276.0	1231.00-1229.00	V08	<1	0.5	4	0.1	1150	<0.1	10	18	6	<0.2	0.8	100	0.1
A－A	10034	1475.78	142.2-143.0	1333.58-1332.78	V09	<1	2.0	2	<0.1	6400	0.3	10	23	29	<0.2	<0.2	116	<0.1
A－A	10034	1475.78	165.0-167.0	1310.78-1308.78	V10	1	0.7	2	<0.1	2400	<0.1	10	119	1	<0.2	1.8	34	<0.1
A－A	10034	1475.78	188.0-190.0	1287.78-1285.78	V11	3	1.5	2	<0.1	5600	<0.1	10	91	1	<0.2	0.6	59	<0.1
A－A	10034	1475.78	248.0-250.0	1227.78-1225.78	V12	3	1.3	4	<0.1	4000	0.3	10	132	<1	<0.2	1.0	50	<0.1
I	10085	1460.48	138.0-139.0	1322.48-1321.48	V13	<1	1.3	2	<0.1	6900	<0.1	10	212	<1	0.4	1.8	33	<0.1
I	10085	1460.48	167.0-167.7	1293.48-1292.78	V14	<1	0.4	2	<0.1	1300	<0.1	10	75	5	2.4	1.0	17	0.2
I	10085	1460.48	183.0	1277.48	V15	<1	2.1	2	0.3	5750	0.6	10	118	48	0.2	0.6	202	<0.1
I	10085	1460.48	214.6-215.0	1245.88-1245.48	V16	<1	2.2	2	<0.1	8500	<0.1	20	119	17	0.2	<0.2	43	<0.1
I	10085	1460.48	231.2-232.0	1229.28-1228.48	V17	2	2.3	4	0.2	8800	<0.1	10	150	6	1.4	0.2	47	<0.1
I	10066	1437.40	99.2-100.0	1338.20-1276.20	V18	<1	<0.2	2	<0.1	440	<0.1	10	5	8	0.2	<0.2	65	<0.1
I	10066	1437.40	160.0-161.2	1277.40-1276.20	V19	<1	0.3	2	0.2	350	0.3	10	7	20	<0.2	<0.2	162	<0.1
I	10066	1437.40	215.8-216.0	1221.60-1221.40	V20	<1	0.3	2	0.5	200	0.6	10	4	130	<0.2	0.2	286	<0.1
I	10023	1488.57	143.6-146.7	1344.97-1341.87	V21	<1	0.3	2	0.1	700	<0.1	20	4	5	0.2	0.6	53	<0.1
I	10023	1488.57	195.4-197.6	1293.17-1290.97	V22	<1	<0.2	2	<0.1	144	<0.1	10	3	1	0.2	<0.2	34	<0.1
I	10023	1488.57	205.9-208.3	1282.67-1280.27	V23	<1	<0.2	2	<0.1	147	<0.1	10	2	2	<0.2	<0.2	30	<0.1
I	10023	1488.57	233.3-236.6	1255.27-1251.97	V24	<1	0.2	2	0.1	460	<0.1	10	2	<1	<0.2	<0.2	35	<0.1
I	10023	1488.57	260.7-263.7	1227.87-1224.87	V25	<1	1.0	2	0.2	1450	<0.1	10	9	5	0.8	0.4	17	<0.1
IV	10030	1496.32	188.0	1308.32	V26	<1	1.9	2	<0.1	6100	<0.1	10	8	5	0.8	0.6	23	0.1
IV	10030	1496.32	202.5	1293.82	V27	2	1.2	2	<0.1	3200	0.9	10	9	4	<0.2	0.4	27	<0.1
IV	10030	1496.32	208.0	1288.32	V28	<1	1.0	4	<0.1	2300	<0.1	10	28	7	7.6	0.8	25	0.6
IV	10030	1496.32	269.3-272.5	1227.02-1223.82	V29	<1	<0.2	2	0.1	47	<0.1	10	4	<1	0.2	<0.2	22	<0.1
IV	10028	1508.05	163.0	1345.05	V30	4	1.0	4	<0.1	4050	<0.1	10	8	<1	0.2	0.4	14	0.1
IV	10028	1508.05	184.0-187.0	1324.05-1321.05	V31	<1	0.9	2	<0.1	3600	<0.1	20	>1000	2	<0.2	1.0	21	<0.1
IV	10028	1508.05	215.5	1292.55	V32	4	1.3	2	<0.1	5100	<0.1	20	148	<1	0.2	0.8	25	<0.1
IV	10028	1508.05	272.5-275.0	1235.55-1233.05	V33	<1	0.4	2	<0.1	1800	<0.1	20	5	5	<0.2	0.8	25	<0.1
V	10067	1429.01	92.5-95.5	1336.51-1333.51	V34	1	1.0	2	0.2	4950	<0.1	20	14	<1	0.2	1.0	19	<0.1
V	10067	1429.01	123.2-126.0	1305.81-1303.01	V35	<1	1.9	2	0.2	6800	<0.1	20	18	<1	0.2	1.0	13	<0.1
V	10067	1429.01	144.5	1284.51	V36	11	1.7	2	0.4	4050	<0.1	10	35	<1	<0.2	0.6	7	<0.1
V	10067	1429.01	196.5-199.5	1232.51-1229.51	V37	<1	0.8	2	1.6	1550	<0.1	10	3	8	0.2	0.6	10	<0.1
X	10039	1484.38	150.9-152.1	1333.48-1332.28	V38	2	2.0	4	0.1	4700	<0.1	10	165	3	<0.2	0.6	85	<0.1
X	10039	1484.38	199.3-216.0	1285.08-1268.38	V39	<1	1.1	2	0.2	2100	<0.1	10	12	3	<0.2	0.2	69	<0.1
X	10039	1484.38	241.0-243.0	1243.38-1241.38	V40	5	0.8	2	<0.1	2550	<0.1	10	75	3	<0.2	1.2	48	<0.1

seems that arsenic content depends significantly on ore quality group. However, if the data from the 2 high grade secondary enriched ores (720 ppm and 324 ppm) is excluded from the 17 then the average becomes 3 ppm and the above relationship is reversed.

- At an elevation of +1280 m the distribution of arsenic in the ore body which extends in NW-SE direction, as shown in Figure 24, presents 3 isolated, irregularly but parallely spaced, anomalous zones (Ln As > 4.0, greater than approx. 55 ppm). In the central anomalous zone, in the south-east section of the ore body, dikes can be seen running in E - W and NW - SE directions, symmetrically placed in the above anomalous zone.

- The central anomalous zone, the largest one of the three, shows a distribution that coincides well with the south-eastern secondary enrichment ore zone at the same elevation (1280 m). (See Figure 25.) Additionally, 2 independent copper anomalous zones (LnCu > 8.5, greater than approx. 5000 ppm) partially overlap the central arsenic anomalous zone and appear to pinch it from both sides. If this arsenic anomalous zone extends vertically, then it will be possible, at the mining stage, to control concentrate arsenic grade by planned ore extraction from the zone.

- On the other hand, vertical distribution of the arsenic shows different behavior from horizontal distribution and, with one exception, the samples showed a low grade (2 - 4 ppm). No variation in arsenic concentration with depth could be seen. This can be thought of as resulting from the small

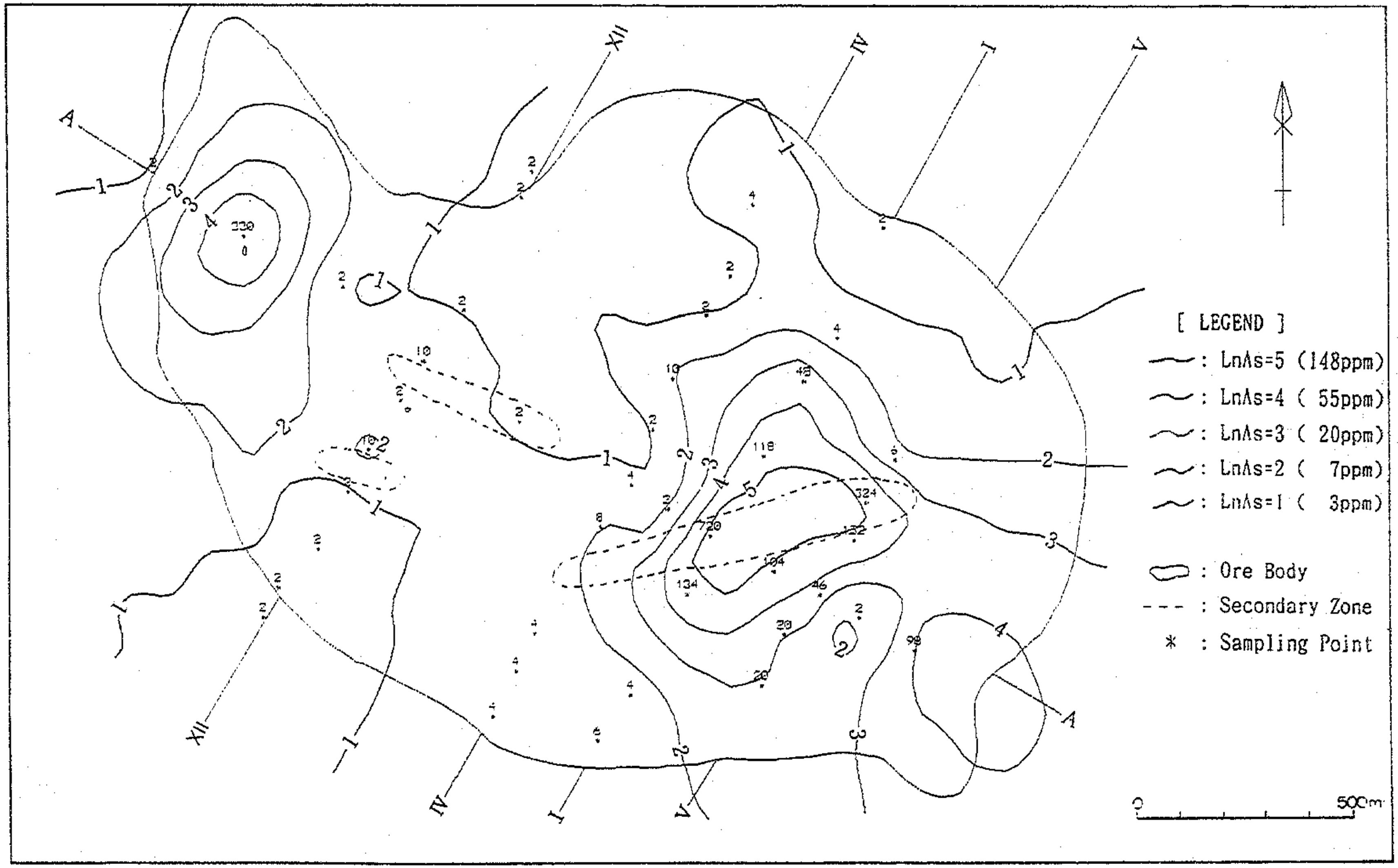


Fig. 24 As distribution at 1280m level

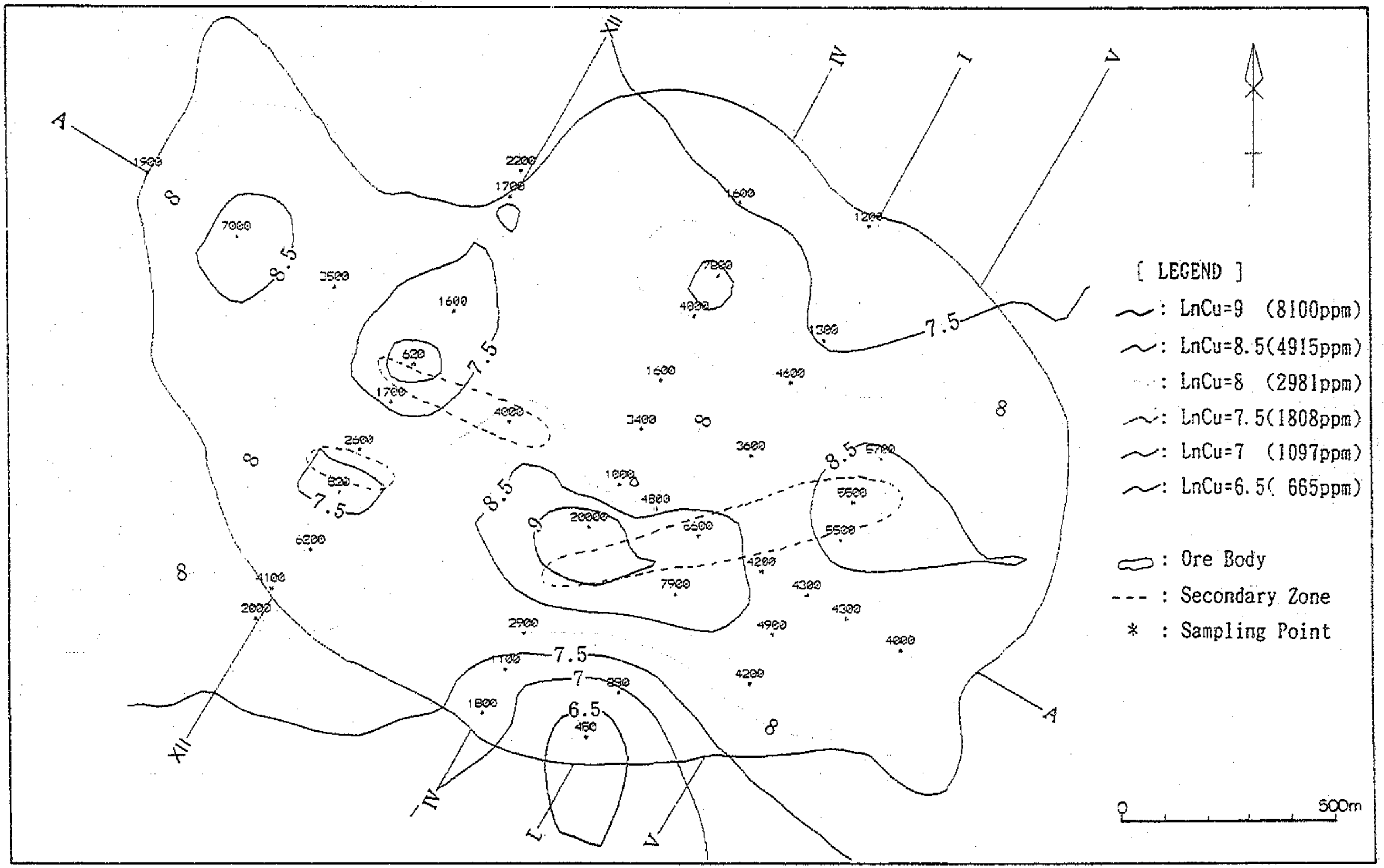


Fig. 25 Cu distribution at 1280m level

number of samples compared with the size of the deposit which meant that hidden arsenic anomalous zones could not be found by the study.

- Accordingly, in order to confirm the vertical continuity of the arsenic anomalous zone found in the south-east section of the orebody(at 1280 m level) it would be desirable to investigate the horizontal distribution of arsenic at 2 further levels (± approx. 60 m) and carry out additional chemical analysis.

  When samples are taken, their collection should be planned bearing in mind the existence of dikes, joints, faults etc. which have grown in the south-east section of the ore bed.

— Results of Mineral Processing Tests

The original objectives of the mineral processing tests were:

- to confirm the flotabilities of secondary enriched sulfide ores and primary ores.
- to investigate the possibility of increasing the recovery rate of copper in copper concentrate.
- to investigate the possibility of maintaining and improving the copper grade in the concentrate.
- to reduce arsenic grade inthe copper concentrate.
- to improve molybdenum / copper separability.

However, the separation of arsenic from copper during mineral processing proved hard as mineralogical studies revealed that the arsenic mineral consists mainly of tennantite.

— The flotability of secondary enriched and primary ores.

Preliminary mineral processing tests on the boring core samples brought back from the Erdenet mine showed results that differed from trends hitherto known in the Western countries in that the recovery rate for both copper and molybdenum were worse for primary ores than for secondary enriched ores. (See Table 42.)

This indicates that, in the future, as the stopes get deeper and the proportion of primary minerals in the mined ore increases, the mineral processing recovery rate, for the current process, will decrease.

— The possibility of increasing the recovery rate of copper in the copper concentrate.

When comparative testing of the mineral processing reagents currently in use at the Erdenet mine (frother: pine-oil-based T-80, collector: amyl xanthate) against reagents thought suitable for porphyry copper ore in the Western countries (several types of frother and collector). The results showed that combinations of MIBC (alcohol-based frother) with 3418A (collector) or AF77A (frother) with 4037 (collector) improved recovery rates, for both primary and secondary ores, by 2 – 3 %. (See Table 43.)

Also, the combination use of dispersant at bulk flotation stage showed better results. (See Table 44.)

— Maintenance and improvement of concentrate copper grade

MIBC-3418A or AF77A-4037 reagent combinations not only improved recoverability but also demonstrated a possibility of bringing about improved copper grade. (See Table 44.)

— Molybdenum / copper separability

The test results showed that, although the currently used thermo-treatment using steam works effectively, separability is improved if the separation flotation stage is carried out using hot water (approx. 60° C) to which sodium hydrosulfide (NaHS) has been added under weak acid condition (i. e. PH 6) (See Table 45).

Table -42 Typical Example of Flotation Test

Type and Description of Ore		Cu Grade	Cu Recovery
Secondary Ore	Feed	0.300	100
	Bulk Froth	12.7	90.4
	Tail	0.033	9.6
Primary Ore	Feed	0.250	100
	Bulk Froth	9.23	82.5
	Tail	0.020	17.5

Table -43 Effect of Dispersion Reagent

Usage of Dispersion Reagent	Description of Ore	Cu Grade	Cu Recovery
Not Applied	Feed	0.253	100
	Cu-C	24.2	71.9
	Cu-M	2.99	15.0
	Tail	0.034	13.1
Applied	Feed	0.255	100
	Cu-C	20.6	83.8
	Cu-M	1.67	5.1
	Tail	0.025	10.5

Table -44 Efficiency of Dispersion Reagent (CMC)

Usage of Dispersion Reagent	Description of Ore	Cu Grade	Cu Recovery
Not Applied	Feed	0.253	100
	Bulk-C	24.2	71.9
	Bulk-M	1.91	15.0
	Tail	0.034	13.1
Applied	Feed	0.255	100
	Bulk-C	20.6	83.8
	Bulk-M	0.57	5.1
	Tail	0.025	10.5

Table -45 Efficiency of Bisulfate Hot Water Flotation Method

Usage of NaHS Hot Flotation	Description of Ore	Grade (%)		Distribution (%)	
		Cu	Mo	Cu	Mo
Not Applied	Feed	0.18	0.014	100	100
	Cu-C	14.9	0.53	86.1	38.4
	Mo-C	10.9	34.4	1.2	50.1
	Tail	0.021	0.0013	12.7	11.5
Applied	Feed	0.18	0.014	100	100
	Cu-C	17.6	0.41	87.2	26.9
	Mo-C	10.2	38.2	1.4	64.0
	Tail	0.021	0.0013	11.4	9.1

4-2-3 Mineral Processing Cost Analysis

(1) Operating costs

Table 46 shows changes in the proportions of operating costs incurred by each item at Erdenet Mine's processing plant. Figure 26 shows comparison of these proportions in 1987 and 1992.

Typically, electricity consumption accounts for approximately 40% of operating costs. Of the electricity cost, 75% is incurred by grinding, excluding Unit No. 5, balls and reagents account for 10% each, water supply for 7% and the power for section No. 5 and steam for Mo/Cu separation for 5% each. Together, these items consume about 80% of the total electricity used by the mill.

(2) Operating Cost Issues

As shown in Table 46 and Figure 26, electricity costs account for 30-40% of operating costs. In recent years, in particular, this proportion has increased dramatically. On the other hand, the proportion taken up by parts decreased drastically, from 8% to about 1%.

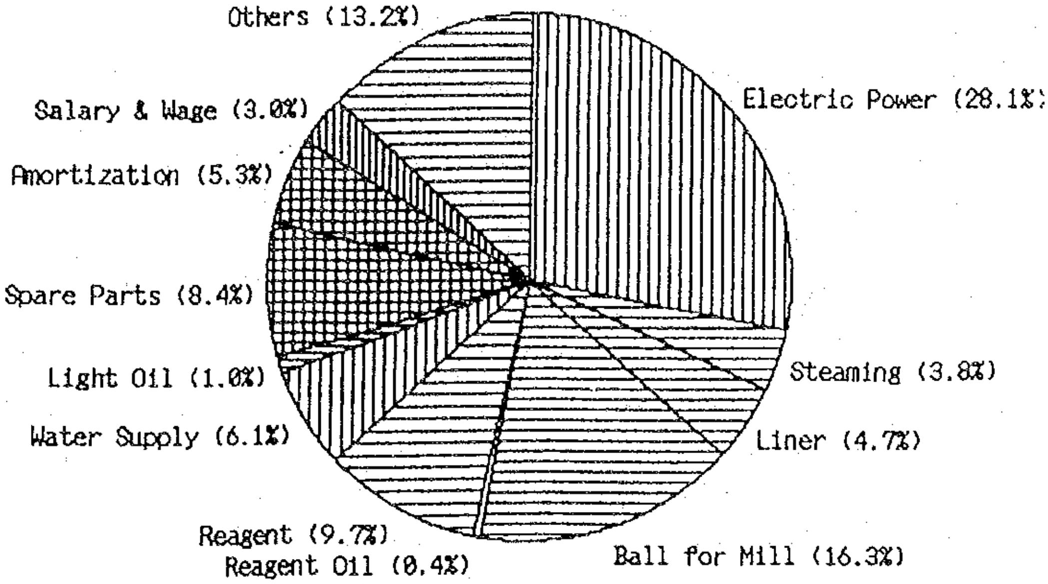
The number of personnel in the mineral processing section is about 1000, as shown in the organizational chart. Of these, the number directly involved in operations is about 700. Even this number is too large, compared with mines of similar size in the Western countries.

As mentioned above, labor costs amount to only 3% of total mineral processing costs, which is a very low compared with the Western countries (10 to 30 %). However, a rise in labor costs could lead to a rapid increase of total costs.

Table 46 Actual Cost Distribution of Process (The Erdenet Mine Mongolia)

No.	Item: Classification	Year	Result 1,987	1,988	1,989	1,990	1,991	1,992	1,993	Total	Note
	Plant Throughput	X1,000t/A	17,124	17,179	17,805	18,654	14,168	16,866	20,500		
	Operation Cost									(%)	
1	Electric Power Consumption	kWh	28.1	30.9	32.0	33.1	40.0	39.1	39.1	38.5	
	·Crushing Stage		2.1	2.4	2.1	6.0	2.1	1.7	2.0	2.0	
	·Grinding stage		15.8	18.1	19.0	17.1	20.1	20.3	18.9	19.1	
	·Flotation Stage		8.5	9.7	10.3	9.2	10.8	10.9	10.2	10.3	
	·Filtering & Drying Stage		0.5	0.6	0.4	0.4	0.4	0.5	0.5	0.5	
	·Reagent Preparation Stage		1.0	0.0	0.1	0.3	0.0	0.1	0.1	0.1	
	·Section No. 5 Stage						6.5	5.7	7.4	6.5	
2	Steaming	m3	3.8	4.2	4.5	4.7	5.6	5.6	4.3	4.6	
3	Liner (Crusher, Mill etc.)	kg	4.7	4.9	3.7	3.4	2.1	2.1	1.4	1.8	
4	Ball (for Mill)	kg	16.3	16.7	15.1	13.8	10.1	11.5	16.2	15.2	
5	Reagent Oil	ℓ	0.4	0.5	0.4	0.4	0.2	0.2	0.2	0.2	
6	Reagent	kg	9.7	10.3	10.3	10.2	7.5	11.0	11.5	11.1	
7	Water Supply	m3	6.1	6.8	7.7	7.6	10.0	7.3	5.5	6.1	
	·Fresh Water		3.1	3.1	4.0	4.1	5.6	3.5	1.6	2.2	
	·Reclaim Water		3.0	3.6	3.6	3.5	4.4	3.8	3.9	3.9	
8	Light Oil	ℓ	1.0	1.0	1.0	1.0	0.8	0.7	0.9	0.9	
9	Spare Parts		8.4	5.6	3.6	3.6	2.3	1.0	6.5	5.4	
10	Amortization		5.3	5.6	5.6	5.8	5.8	2.8	1.1	1.9	
11	Salary & Wage		3.0	3.3	3.4	3.5	4.6	3.0	1.0	1.6	
	·Engineer & Technician		0.4	0.4	0.4	0.5	0.6	0.4	0.1	0.2	
	·Worker		2.6	2.9	3.0	3.0	4.0	2.6	0.9	1.4	
	·Employee		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	·Service Worker						0.0	0.0	0.0	0.0	
12	Others		13.2	10.2	12.7	12.8	10.9	15.7	12.3	12.8	
	Operation Cost Total (%)		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
	Operation Cost Total (Tg)	X1,000	284,602	257,636	258,156	276,293	462,954	2,018,668	9,711,661	13,269,970	

1987



1992

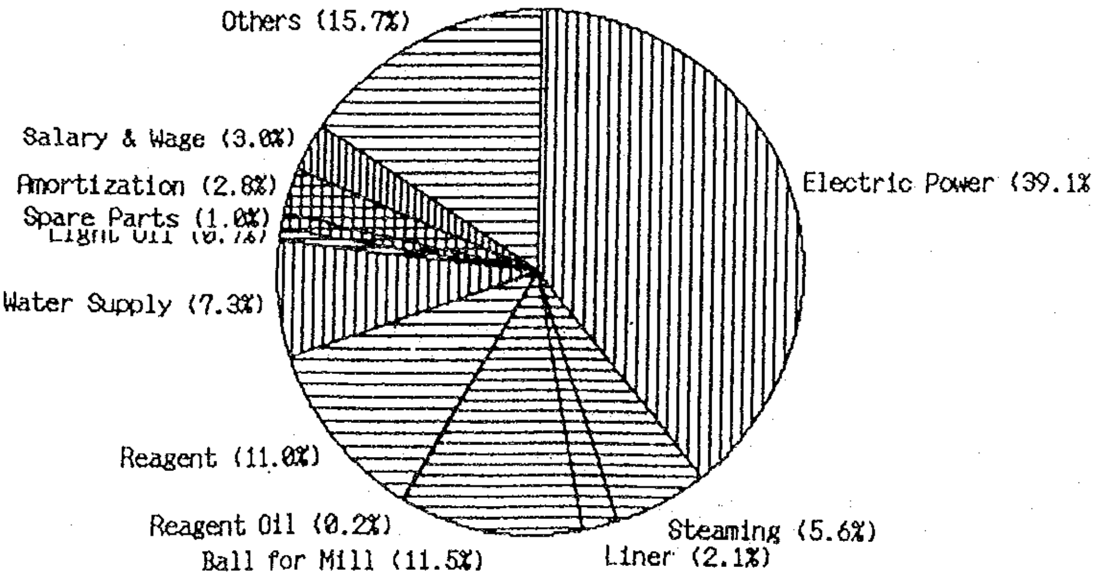


Fig. 26 Operation Cost Rate

4-3 Workshop

The workshop consists of a casting plant and a machining plant. Of these plants, the casting plant casts abrasion resistant and corrosion resistant parts and other mechanical parts required in several areas of the mine. The casting capacity of this plant is 6,500 tons per year which is quite large even in world standard. The machining plant is composed of a machining shop which fabricates the materials cast in the casting plant and the materials purchased from outside of the plant, a plate working shop which cuts and welds the steel materials, a maintenance and assembly shop of the machines and a special fabrication shop such as a motor repair shop and a rubber products manufacturing shop.

The workshop composed of these two plants is an important department contributing to maintain the facilities for the production of Erdenet Mine.

The survey was conducted to determine not only the sufficiency of production capacity and technical standard of the workshop to maintain the present production quantity of the mine but also to determine whether it has the capability to compete with the developed overseas competitors, to improve more efficient production and to have higher development. A diagnosis was done based on the results of the survey.

The results of the diagnosis are described in this chapter for each plant.

4-3-1 Casting Plant

(1) Kind and production quantity of cast products

As shown in Figure 27, about 77% of the total production is high manganese cast steel for abrasion resistance use. As to the application of the products, about 80% of the total product, as shown in Figure 28, are the parts used in the mineral processing plant. Meanwhile, there are some products sold outside of the mine, which represents only about 5.9% of the total product.

(2) Chronological change in production quantity

As shown in Fig. 29, it was normal production quantity up to 1989 but at present, after the fall of USSR, the achievement of the programmed production has dropped drastically to 40%. The reason for this is assumed to be as described below.

1) Lack of electric power : Drop of operating efficiency due to domestic energy system and lack of electric power supply from abroad (Russia) and also by the indifferent and emergency power failures.

2) Lack of raw materials : By the introduction of market economy, the payment for the raw materials purchased from abroad has to be done by US dollars and a delay in delivery of raw materials is caused due to delayed payment caused by lack of US dollars.

3) Lack of manpower : With the introduction of market economy, many skilled workers retired looking for other jobs.

4) Deterioration of equipment : It has been 12 years since the start of operation but no renewal of equipment and machine had been done.

Of the above reasons, Nos. 1), 2) and 3) are big and macro problem such as

Fig. 27 Type and Production of Cast Products

Production Schedule for 1993

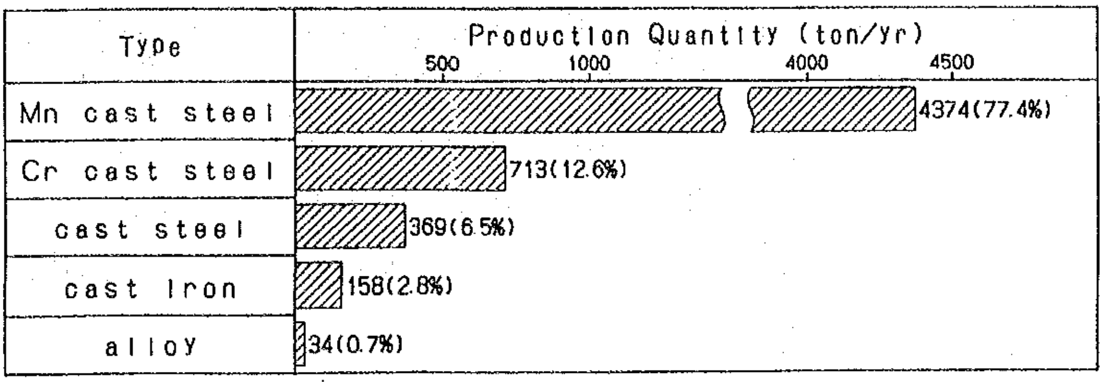


Fig. 28 Production Quantity for Each Application

Production Schedule for 1993

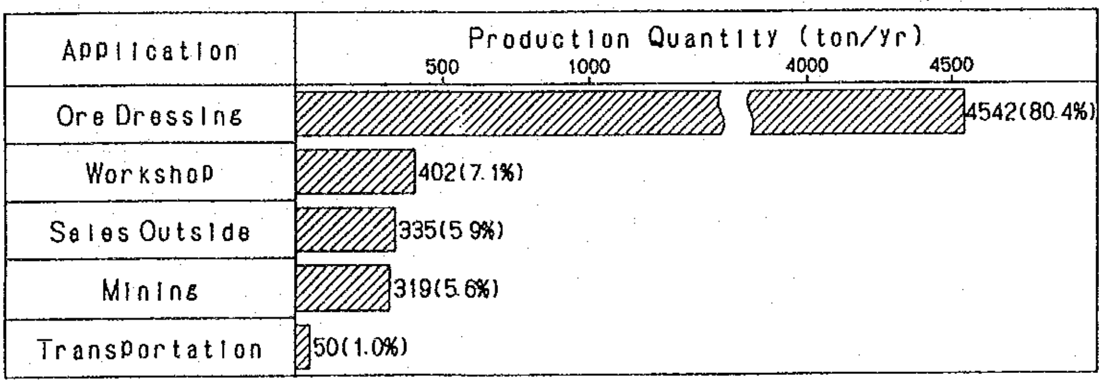
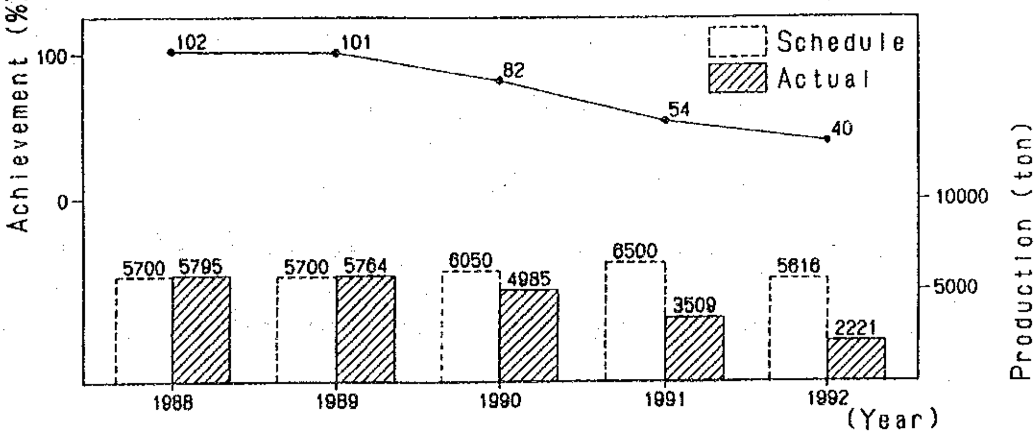


Fig. 29 Recent Production of Cast Product
(Schedule and Actual)



national energy and economical problems which takes time to be solved but No. 4 is a problem directly connected to the production and maintenance of the concentrate production and it is an urgent problem which can be solved by the mine itself and should be improved.

(3) Present situation of casting equipment

The casting facilities are deteriorated as stated in the above item 4-3-2-(2). The present situation of the facilities is as described below.

1) The facility to knead and blend the casting sand : The facility is deteriorated and by dust generation caused by scattered sand and binding materials (contains large amount of free silica), the working environment is very bad.

2) The molding facility : The molding plant is composed of casting plant and mold preparation plant and the casting plant is small for its capacity of 6,500 tons/year and need to be expanded. Meanwhile, in the mold preparation plant, there is a vibrating type mold machine for manganese cast steel which is the main product (62 % of total production). Because of deterioration, this machine is often in trouble resulting in low working efficiency and poor molding accuracy and it has to be renewed.

3) Melting facility : In the center of the plant there are furnaces for melting the materials and there are three furnaces with 3 tons capacity each. The maximum weight of a piece of cast material is 3 tons and therefore, it is necessary to newly install a furnace with a capacity at least larger than 6 tons. The smoke and dust emission during melting is so much and the furnaces should be modified to be able to prevent this emission.

4) Product cleaning facility : This is a plant to demold the cast product, remove sand and further clean the surface of the cast material. In this plant, the capacity of the shakeout machine is insufficient (5 tons are loaded on 3 tons tolerable loading capacity), resulting in too much repair time which drops the working efficiency which is the major cause of production drop in the overall plant. It is necessary to renew this machine. Meanwhile, the plant to clean the surface of the product should be laid out depending on the kind of product to improve the efficiency of cleaning work.

5) Working area of the entire plant : The entire plant is designed for 6,500 tons/year production but the present actual production reaches only 2 to 3,000 tons/year. The working area seems to be squeezed. The plant area should be expanded even with the present production capacity in order to improve the production efficiency.

(4) Present situation of production technology

The casting process is CO_2 method which is of high technological standard. However, the rate of final product rejected, in other words rejection rate is high. Figure 30 shows the rejection rate of 21% which is becoming worse since 1991 against the present target rejection rate of 5%. Further, from Figure 31 which shows the cause of rejection, the following features can be highlighted.

1) Half of the rejection is due to poor molding which can be assumed as due to poor mold preparation and inadequate strength and characteristics of the molding sand. To solve this problem, it is effective to adopt the VRH method which is the improved type of CO_2 method.

2) Mistakes in pouring and melting are highly noted which are caused by

Fig. 30 Recent Rejection Rate

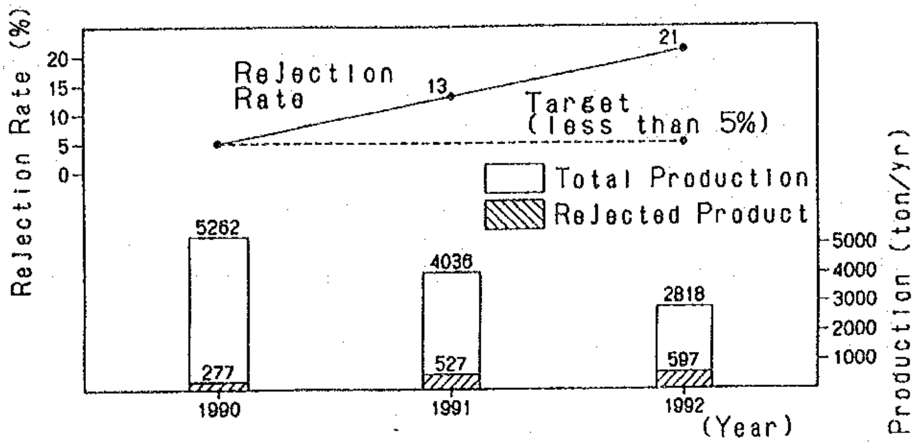
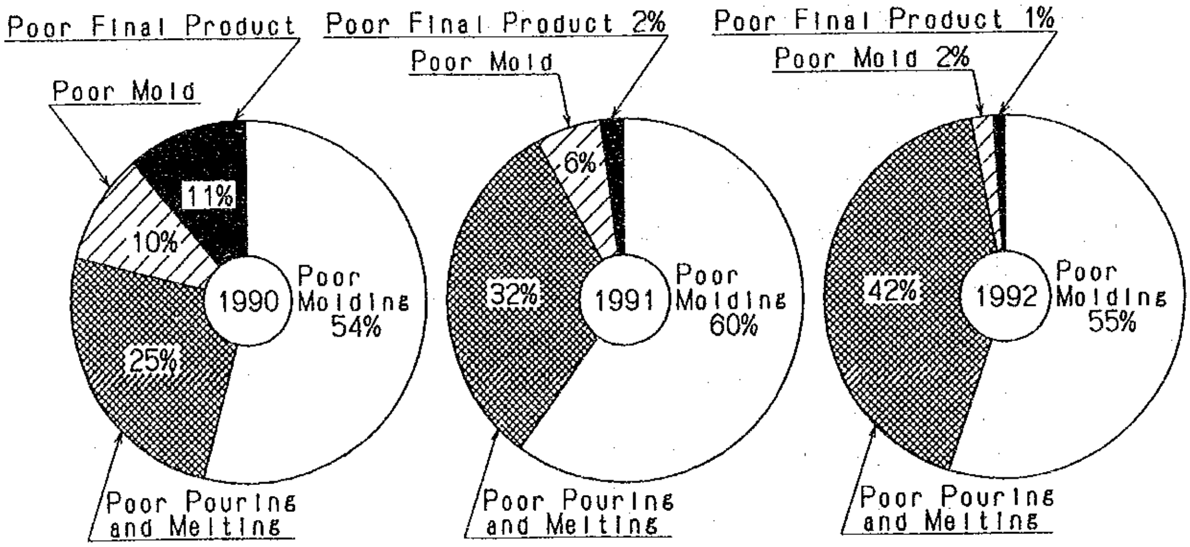


Fig. 31 Breakdown of Rejection



poor pouring operation and melting mistakes (mainly improper contents of the product) and the former should be solved by the improvement of skills of the operators and the latter should be solved by accurate content analysis at site to prevent components other than specified to be fed into the pouring process.

It is important to improve the production yield by quality control.

(5) Production cost

There are cost data but at present, the foreign exchange rate is fluctuating widely and with when expressed in Tg, it is difficult to compare the production cost with other foreign producers. Therefore, the data of 1989 when the cost was comparably stable was analyzed. (Refer to Fig. 32.) As a result of this analysis, the following three points have to be improved.

1) Decrease the consumption of materials

The rejected products should be reduced by improving the yield and the life of the products should be extended by the improvement of quality in order to decrease the consumption of materials.

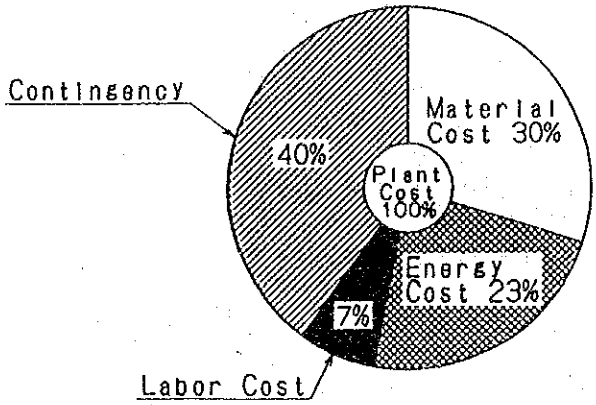
2) Decrease the energy cost

The useless energy consumption should be eliminated by decreasing the rejection rate and energy saving measures should be implemented.

3) Decrease of equipment cost

The contingency cost breakdown shows that 90% is for the repair of the equipment. This is due to the deterioration of the equipment and by renewal of these equipment, the repair cost should be decreased. Further, the improvement

Fig. 32 Total Cost of Cast Product in 1989
(Example of Mn Cast Steel)



of working efficiency should be planned and equipment to meet the use should be selected. The repair and maintenance organization should also be reinforced.

(6) Quality control

As a quality control, characteristics of molding sand, temperature and composition of molten metal, hardness and shape of mold, and final product are inspected by the operators and quality control engineers. However, at present, the production yield is bad and the result of the product analysis indicates that the correct composition as specified is not respected. This means that quality control is done but it is not bearing sufficient fruit. On the other hand, it is apparent from Fig. 33 that the life of the product is shorter than the products of Russia which is the target. In order to improve the situation, following improvements are necessary.

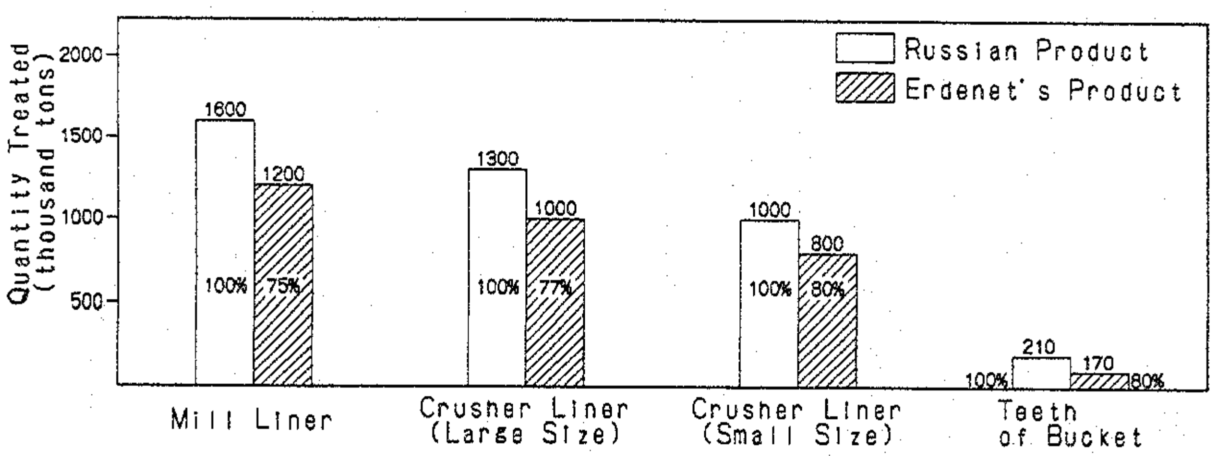
1) Reinforcement of composition and temperature control of molten metal

In order to adjust to the target composition, it is important to establish a system to quickly and easily analyze the molten metal during melting and to quickly adjust the composition not waiting for the analysis of the final product. The same thing can be said to the temperature and it is necessary to prepare the measuring instruments to enable this system.

2) Control of characteristics of molding sand

The control of sand used in the plant is as important as the control of molten metal. For this purpose, it is necessary to have analyzers to know the physical properties as well as chemical compositions of the sand.

Fig. 33 Comparison of Product Life



3) Control of CO_2 gas consumption

Under the present operating conditions, the quantity of CO_2 gas blown in and the quality of the mold are judged based on the experience of operators and the control of molds is also not sufficient. This caused generation of reject products as well as over use of CO_2 gas resulting in increase of production cost.

To solve this problem, adopting the new process called VRH, which is explained later, will contribute to great improvement.

(7) Subcontracted works

About 300 tons of cast products were sold outside of the mine five years ago (1988) and it is programmed to receive subcontract work of 335 tons from outside the plant in 1993. This work is mainly for the companies in the industrial group of Erdenet Mine such as cement and coal plants. In future, the improvement of technology and stabilization of production should be done and expand the sales outside the mine in a following way.

1) More aggressive sales of cast products to outside of mine

For this purpose, it is necessary to have stable production expansion of the plant as well as improvement of the quality. The client, for the time being shall be the companies in the industrial group but should be expanded to companies outside the group, to automobile parts, and public use.

2) Introduction of new technology

As one of the high casting technology, there is a die-casting method for precision and mass production. This method is not done in the plant but for future development, a die-casting facility should be introduced in the casting plant to start production of automobile parts and other domestic household materials. By this introduction, the metal mold manufacturing technology which is the basis of precision technology and also of industrial technology can be established.

4-3-2 Machining Plant

(1) Kind and production quantity of products

The major products are machine fabricated products, plate worked products and rubber products and aside from these, the work of the plant also includes build up welded product for abrasion resistant materials, and repair and assembly of the machines and tools. Therefore, this plant does not do the maintenance and repair of other plants but production of its own products and repair and assembly of materials used in its own plant. The plan and actual result of production of major products are shown in Fig. 34, 35 and 36.

Compared with the actual result in 1988 when it seemed to be under normal condition, the production is all reduced by more than 50% except the rubber products. This is because of the lack of manpower, raw materials and electric power and as already stated, this can be solved by time. Particularly for the machine fabrication, it is directly influenced by the reduction of production in the casting plant. In the machining plant, compared with the casting plant, it is difficult to imagine the decrease of production due to deterioration of equipment of poor maintenance.

(2) Equipment and facility in the machining plant

Speaking about the equipment and facilities, the machining plant can cope with almost all machining work required in the mine and they are sufficient. However, when compared with the facilities used in the present developed countries, the fabrication accuracy, speed, productivity, energy saving and manpower saving are quite poor. This machine fabrication field is a field where the technical improvements in the developed countries are significant. This does

Fig. 34 Production of Major Fabricated Products (Machined Products)

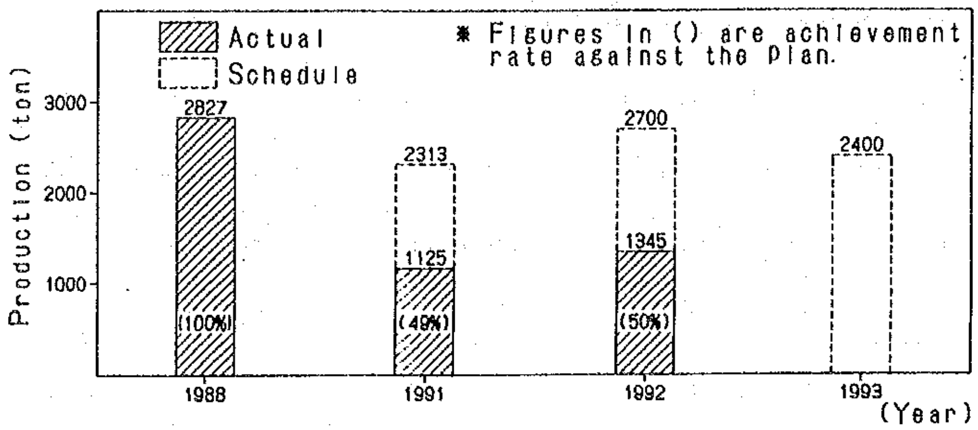


Fig. 35 Production of Major Fabricated Products (Plate Work)

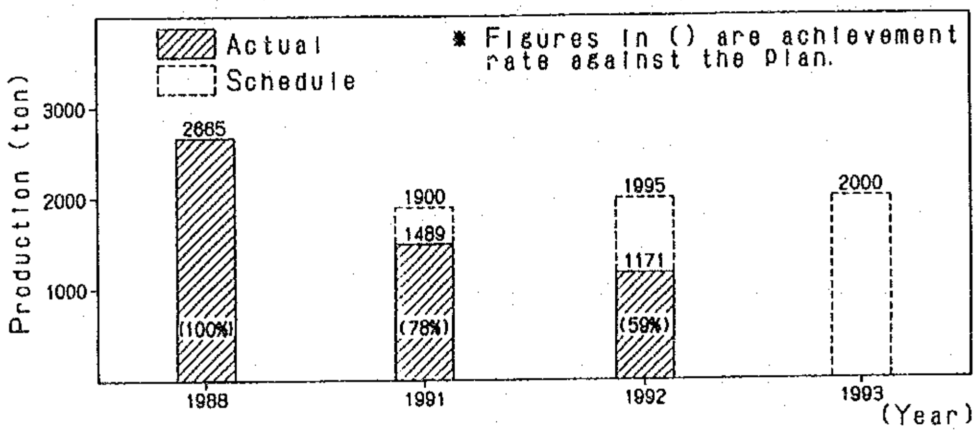
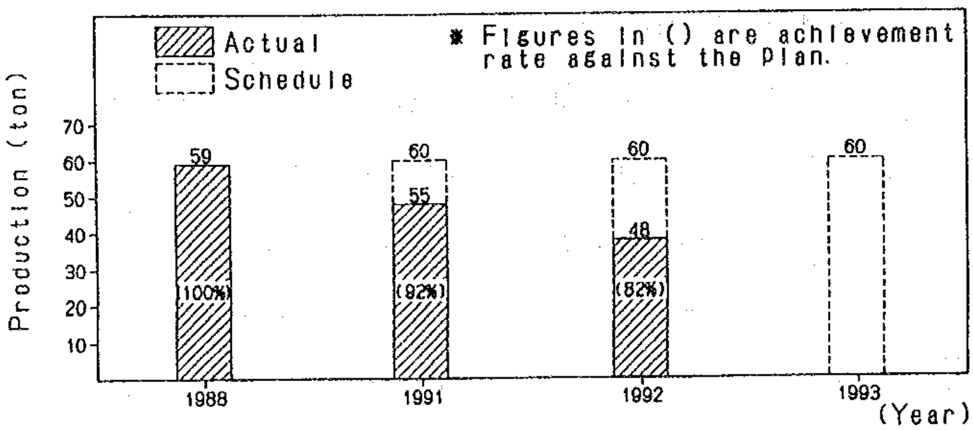


Fig. 36 Production of Major Fabricated Products (Rubber Product)



not mean that the existing facilities have to be renewed immediately but the following points should be improved.

1) Introduction of NC facilities

In addition to its role to maintain the production of the mine with the existing facilities, it has to expand the subcontracted works and establish a technology which can compete with the foreign countries. For such purpose, the introduction of NC machine which is the application of the most high technology in the overseas countries will enable to learn the actual situation of facilities in the developed countries as well as to start the modernization of the facilities.

2) Improvement of existing facilities for manpower saving

The existing facilities are almost all manually operated. However, considerations should be made for the future increase in labor cost, manpower allocation for the subcontracted works and production expansion. In other words, manpower saving by semi-automation of the existing large size turning table, large size drilling machine and large size plainer should be considered.

With the modification to install special sensors, electric control panel and alarms, the system could be established to have operation done automatically until the preset work is finished and then giving a signal to the operator that the work is completed. With this system, one operator can handle several (3 to 4 units) machines at the same time. Meanwhile, it was also considered to modify a part of large size machines to introduce NC system but this measure will require quite big modification of the existing facilities resulting in high cost and therefore, the above system is the best. The manpower becoming free by this modification can be assigned to sales of the products outside the plant which can expand the business.

3) Filling up the insufficient equipment

As already stated, the plant has sufficient equipment and facilities but a sawing machine for a large diameter (500 mm and a precision jig boring machine for a large diameter which is for a cylinder fabrication has to be reinforced.

(3) Present situation of technology

The plant can be said to have technology required to fabricate the parts and devices required in the mine. Meanwhile, aside from a general machining technology, the plant has special fabrication technologies such as chromium plating, high frequency heating, rubber products, immersed coal tempering and other heat treatment technology. Further, it is producing in-house quite a number of bolts and nuts. These products are of many types but in small quantities and is not technically difficult but takes manpower which means can expect great effect is manpower saving is done. Therefore, the followings are proposed.

1) For the special fabrication works such as chromium plating, high frequency heating, rubber products, , the work can be subcontracted to outside producer together the equipment or to establish a subsidiary company which can work on this special field to improve the productivity and technology thereby reducing the cost.

2) Introduction of bolt-nut continuous production machine

The bolts and nuts which are the products repeatedly produced and in many varieties but in small quantities, a specialized automated machine should be installed to save manpower and improve the productivity.

(4) Production cost

For the cost data, the analysis is done on those of 1989 when the production was comparatively stable and the results are shown in Fig. 37 and Fig. 38.

1) Cost of plate worked products

The rate of contingency is high and it is composed of repair of equipment, depreciation and maintenance. Further, it is said that 50% of this cost is for the maintenance and repair of equipment. It is also noted that the labor cost is about twice in comparison with the cast products, which means that manpower saving will influence greatly the cost saving.

2) Cost of machine fabricated products

The same thing as that for the plate worked products can be said on the contingency.

The rate of labor cost is higher than that for the plate worked products and labor cost saving by automation or semi-automation of machine will contribute greatly to reduction of production cost.

(5) Subcontracting work from outside the mine

Judging from the quantity of equipment in the plant, its high technical standard and kind of fabrication equipment it has, it is possible for this plant to manufacture domestically marketable products as well as products required in the plants other than mines. With the addition of some special equipment and a little advanced machines, it is possible to meet wider requests which will contribute to improve the profitability and improvement of technology. A specific target for this sales is :

1) Automobile parts for public use

Fig. 37 Unit Cost for Machining (Per 1 kg. 1989 Plan)
(Wihtin the range of 10 to 50 kg of products)

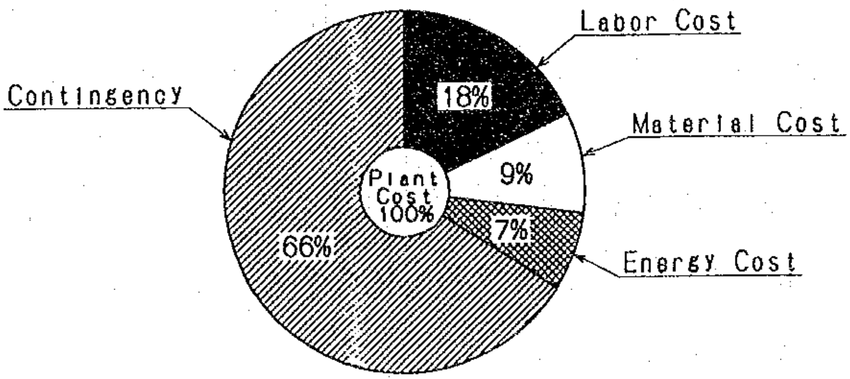
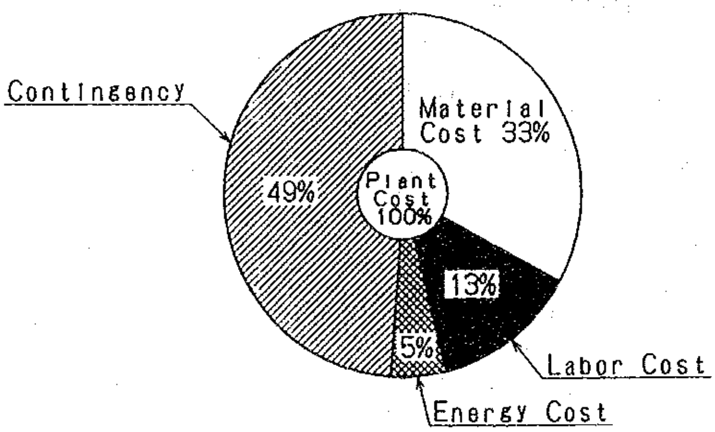


Fig. 38 Unit Cost for Plate Working
(Per 1 ton)



2) General industrial tools

3) General machine parts

For such purpose, a spline broach and hypoid gear fabrication machine as well as know-how on machining and heat treatment should be introduced.

4-4 Utility

4-4-1 Electricity

(1) Electricity Consumption at Erdenet Mine

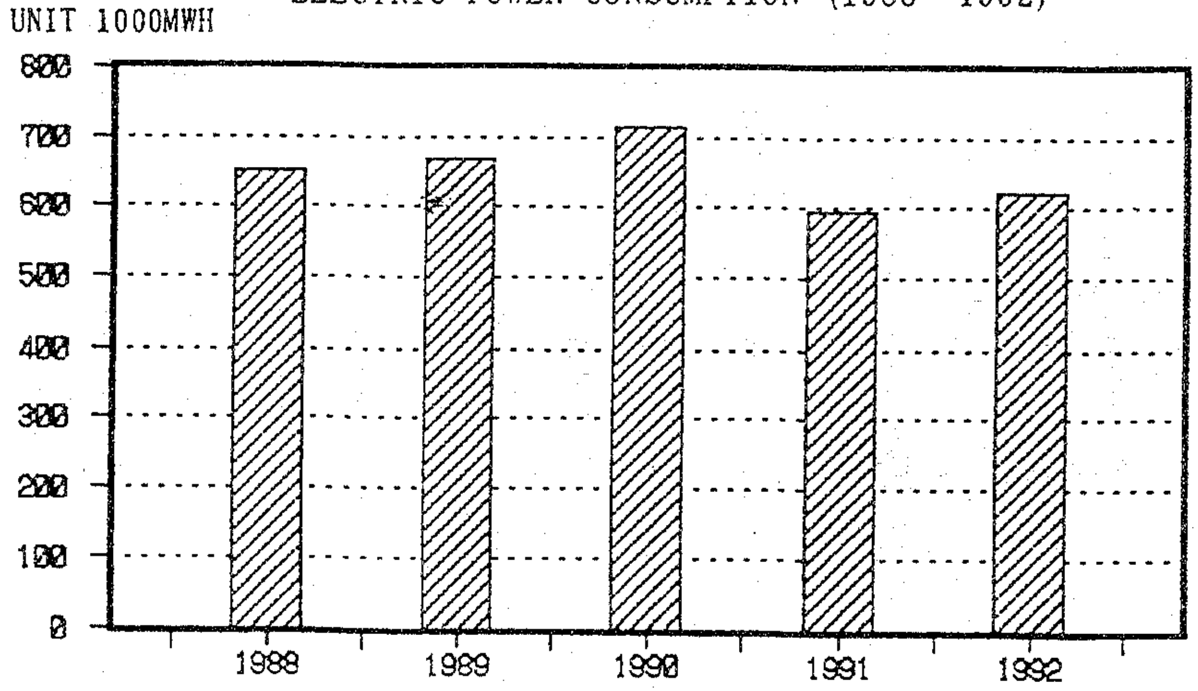
Erdenet Mine uses 100 MW of electricity during winter, and 85 MW during summer. All electricity used at the mine is supplied by the state-run Central Energy System. However, in recent years, the supply of electricity from this utility has failed to meet demand, with frequent restriction in the amount of electricity the mine receives which has become the major cause for production cutbacks at the mine. The frequency of power restriction, including power failures, for all the plants, rose from 94 in 1990, to 975 in 1991, 481 in 1992 and the situation has not been improved as of June, 1993.

These power restrictions have been of short duration, and in total have amounted to cuts of only about 10% in the total amount of programmed electricity supply to the mine per year. However, with supply shortages occurring on average two or three times a day, the mine has not been able to achieve its production targets.

Securing an adequate supply of electricity is the most important consideration in any modernization program of Erdenet Mine. Figure 39 shows the actual results of electricity supply in the past 5 years. The electricity consumption has shown increase every year up to 1990 but in the years 1991 and 1992, with a direct influence for the above mentioned power restriction, the actual consumption has dropped to 75% of the target in 1991 and to 80% in 1992.

Fig. 39

ELECTRIC POWER CONSUMPTION (1988～1992)



(2) Electricity Supply by the Central Energy System

Most electricity is generated by five thermal power plants around Ulaanbaatar, with an additional supply from Russia and transmitted to the consumers along power lines at 220 kV, 110 kV and 35 kV. The combined generating capacity of the five thermal plants is 800 MW. However, due to operation problems at Ulaanbaatar No. 4 plant which accounts for 70% of this capacity and general deterioration of the facility and lack of spare parts, the supply capacity at present has dropped to 500 MW. Moreover, the power plant in Ilyukshik area is suffering from the operational problems which results in drop of power supply from Russia to 40 MW at present, not 70 MW as in the past.

Power generating capacity of the thermal power plants

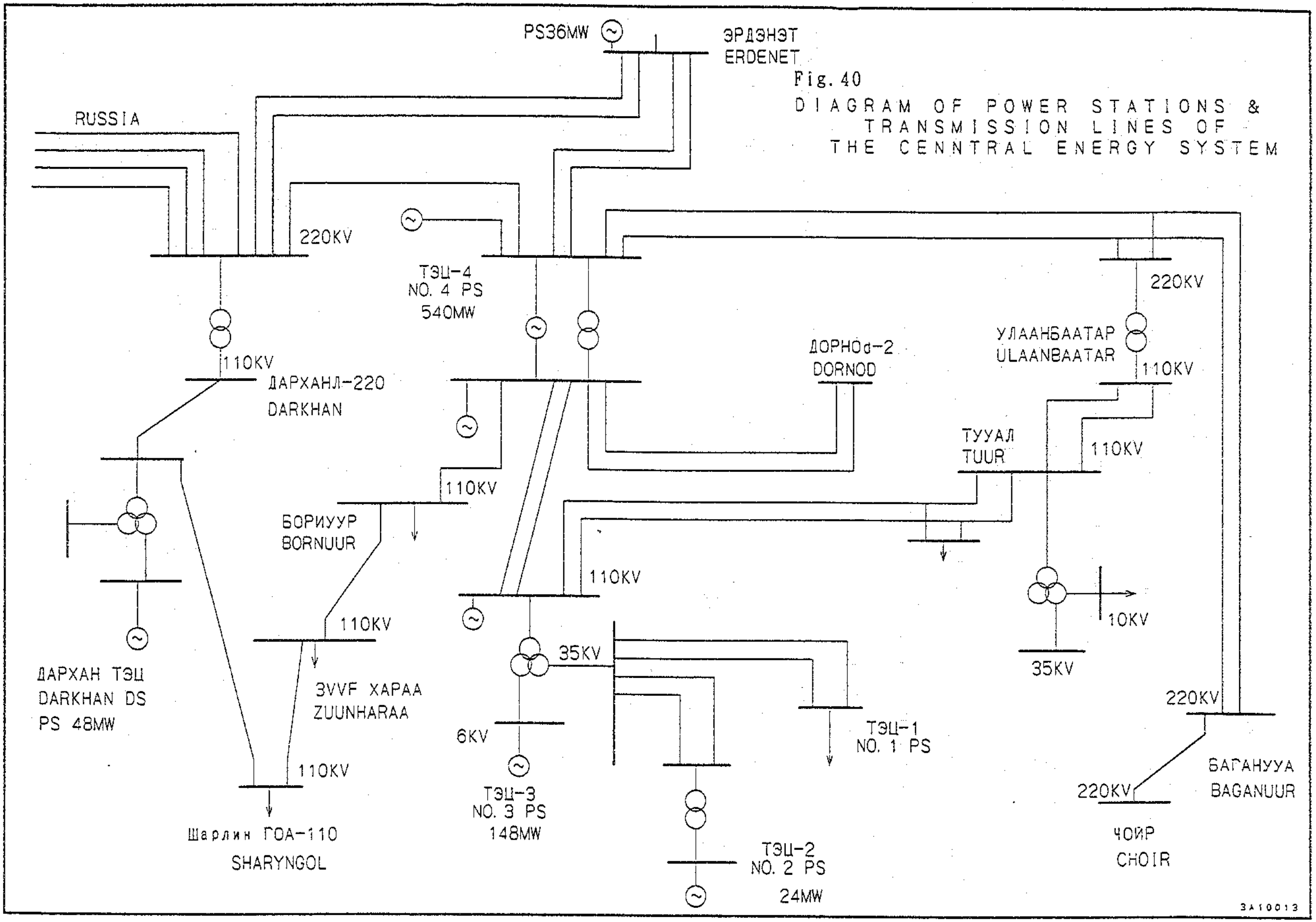
Ulaanbaatar No. 4	540 MW
Ulaanbaatar No. 3	148 MW
Ulaanbaatar No. 2	24 MW
Dalhan	48 MW
Erdenet	36 MW

In parts of Mongolia not serviced by the Central Energy System, electricity is locally produced by a diesel generator. The area serviced by the Central Energy System is 30 of the country and the supplies to 50 % of the national population. It supplies to the major regions of the country including cities and is the major power supply system in Mongolia. (Fig. 40)

(3) Electrical Facilities at Erdenet Mine

Fig. 40

DIAGRAM OF POWER STATIONS & TRANSMISSION LINES OF THE CENNTRAL ENERGY SYSTEM



The electricity supplied by the Central Energy System at 220kV is dropped to 110 kV by a transformer and a part of it is further dropped to 35 kV. The major plants receive a 110 kV supply while the 35 kV supply goes to the smaller plants. As a highlighted facility, there is a long distance transmission line of 60 km extending to water intake pumping station on the Selenge River. (Fig. 41)

The voltage to the facilities is 6,000 V for a high capacity equipment, 380 V for the medium and 220 V for lighting and similar facilities.

There are about 1,300 motors with an output of more than 20 kW and of these, 107 are rated above 500 kW, including 12 crushers (each 4,000 kW) for mineral processing plant which account for one third of the total 100 MW electricity demand of the mine. these large motors have major influence to the amount of power consumption.

(4) Electricity Rate

The contract with the Central Energy System recognizes the following tariff periods:

Day time	06:30 hrs to 17:30 hrs.
Night time	17:30 hrs. to 22:30 hrs.
Midnight time	22:30 hrs to 06:30 hrs.

Comparing the unit rates, the night rate is five times the day rate and the midnight rate is one-fifth of the day rate. This tariff is intended to give priority to the domestic consumption and control the peak demand by the industrial consumption. The actual unit rate is US$0.051/kWh.

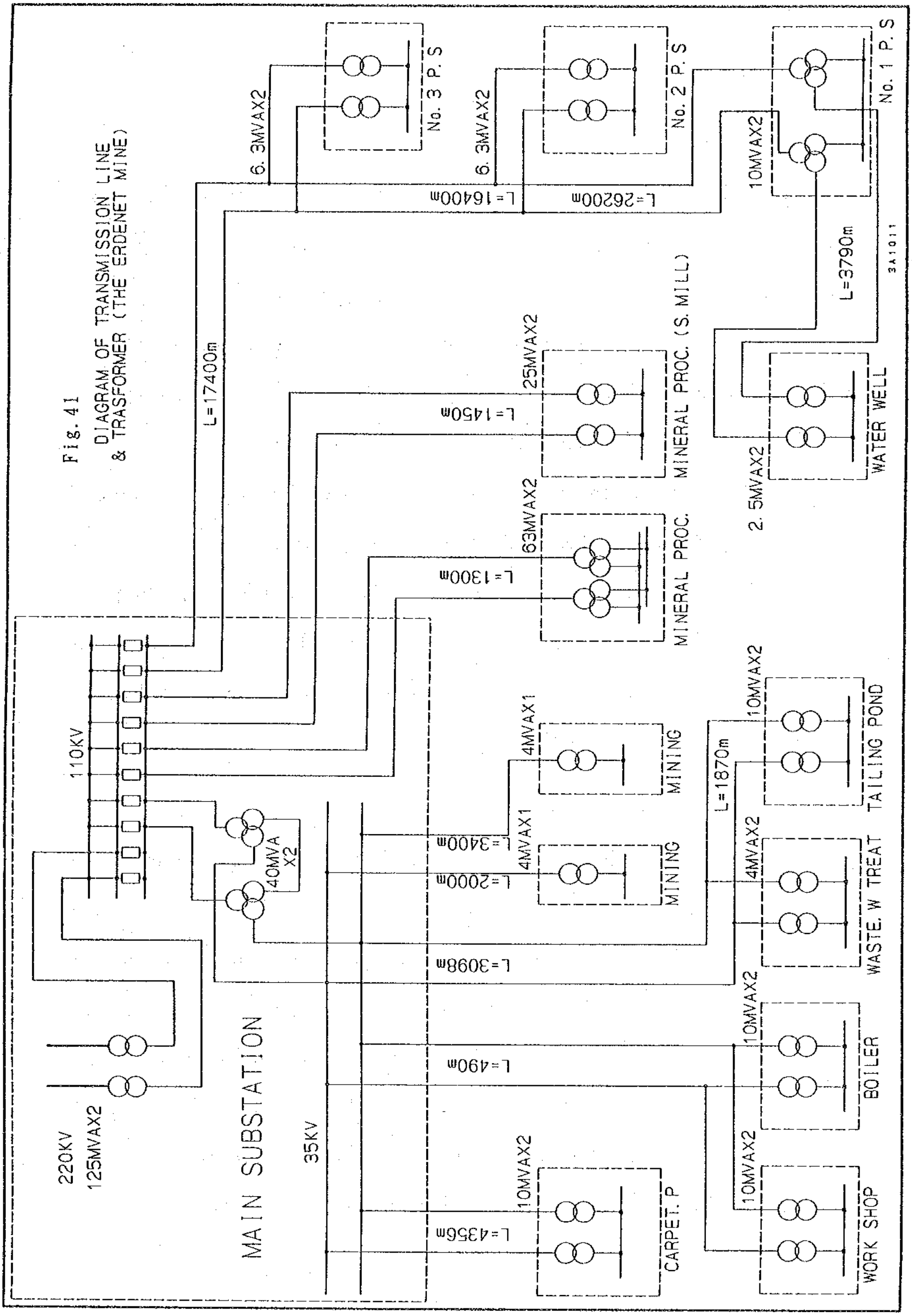


Fig. 41 DIAGRAM OF TRANSMISSION LINE & TRASFORMER (THE ERDENET MINE)

(5) Diagnostic review

—Present electric power consumption

The electric power consumption is small in summer, but high in winter, the supper consumption being about 90% of the winter. (Please refer to Figure 42.) As the plants are operated 24 hours a day, hourly fluctuations of the electric power demand in a day are as small as plus or minus 5%. (Please refer to Figure 43.) From the supplier's stand point, the mine is a very stable power consumer.

The rates of power consumption by each plant against the total power consumption are shown in Table 44 and as shown in the Table, the mineral processing plant consumes 69% and water section consumes 18%, and these two sections consume 87% of the total consumption. Therefore, the energy saving and modernization program which are explained after should be focused on these two sections. In general nationwide electric power distribution situation, Erdenet Mine has priority to receive the electric power.

—Electric power restriction

As mentioned in item (1), the frequent electric power restriction causes production losses not only while it occurs but before and after as well, such as losses by preparations for a power shut down, time to restart and unstable operation which are difficult to detect from the statistic operation data. In order to prevent such power restrictions, it is necessary to improve and reinforce the power plants of the Central Energy System. At the same time, Erdenet Mine itself must also urgently promote installation of power generating facilities effectively utilizing the existing facilities in order to recover the dropping

Fig. 42 ELECTRIC POWER CONSUMPTION

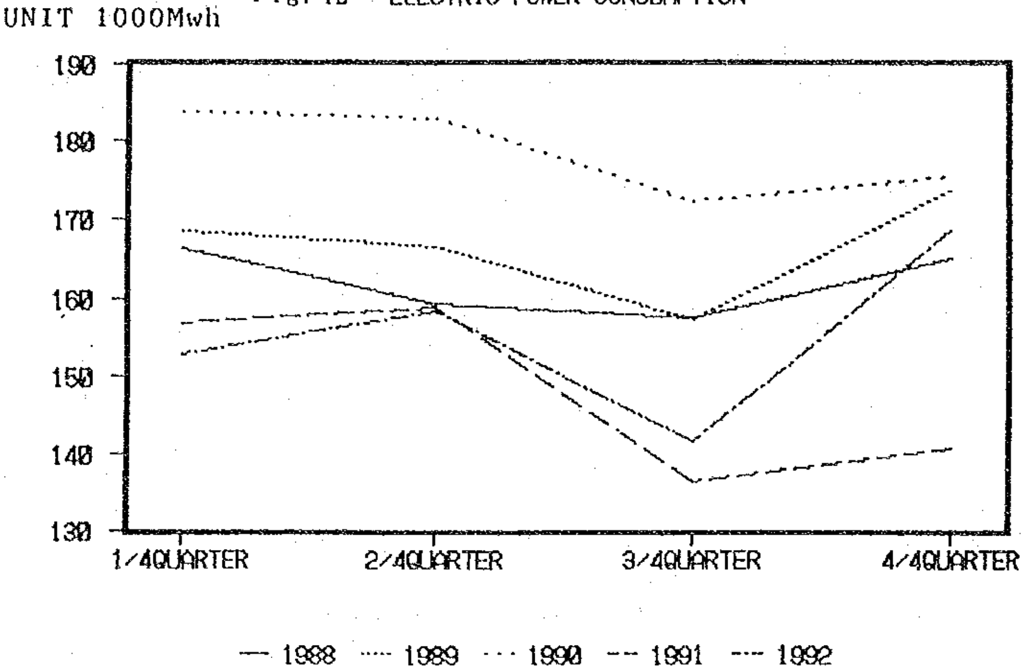


Fig. 43 DAY LOAD CURVE

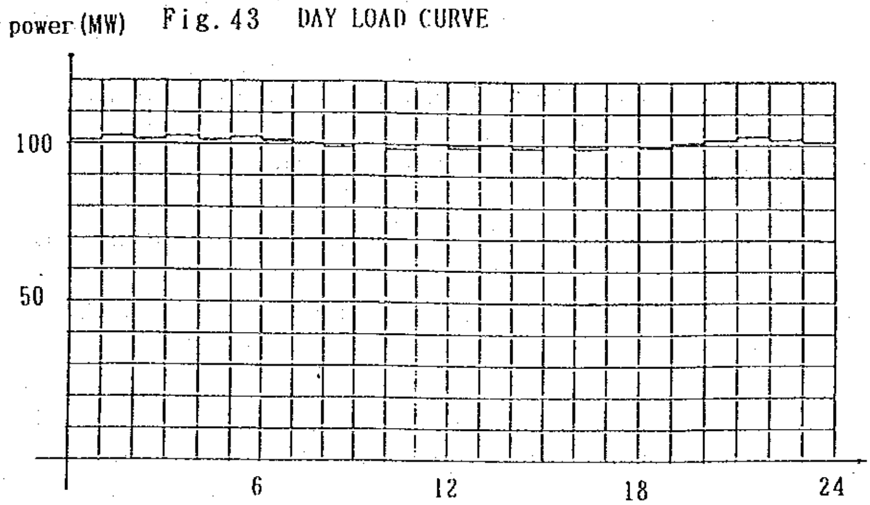
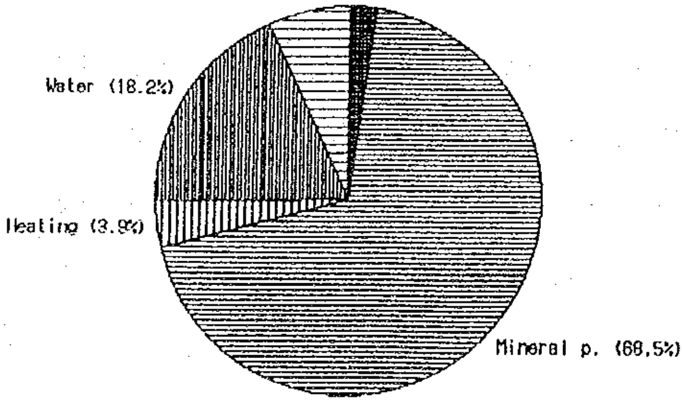


Fig. 44 Electric Power Consumption (%, 1993estimate)



production and moreover to expand it as well as to secure the emergency power source for the tailing transportation pump which will be put to operation shortly.

—Prospect for energy saving

It is essential to establish an energy saving system as well as to secure a stable power supply in order to overcome the insufficient power supply from the Central Energy System, a particularly high power unit cost in the mineral processing and a future trend of increase in unit cost due to drop in ore grade and changes in operating conditions such as tailing dumping.

The electrical facilities were examined in the light of these objectives.

•Losses along the transmission lines and from the transformers total to about 1.5% of the total electricity used which is a comparatively small figure, Power loss along the water intake pumping line which transmits the power over a long distance of 60 km is less than 3%. This is because the power is transmitted at a high voltage of 110 kV which means the facility is with some allowances but in the other way around, this means that it is advantageous for future increase in ore treatment.

•There are large capacity motors such as the crushers for mineral processing plant mentioned in the above paragraph (3) and more for the pumps. There are about 130 motors of 100 kW or more and the largest being 2,500 kW. For higher energy saving at the pump motors, a variable speed motor is very effective but at present, these variable speed motors are used only in some parts due to the fact that the processes such as mineral processing require only constant speed feed. It is necessary to examine whether the constant feed operation is best fitted for operation or not and at the same time, it is necessary to promote a study on the energy saving by adopting the variable speed motors.

●In Japan, it is customary to use an inverter in a motor of 100 kW or less to enable it to run at a variable speed. Such inverters are standardized in Japan and are easily installed to the existing electrical facilities and serves as an effective measure to save energy in a small capacity motors. These inverters have not been used in Erdenet Mine and it is therefore recommended to use them first in a small capacity pumps to promote energy saving.

4-4-2 Steam and Hot Water

(1) Boiler Facilities

Erdenet Mine has six units of pulverized coal combustion boilers generating 75 tons of steam per hour per unit. For a period between November and February, three units are in operation and one or two units in operation during the rest of the year. This means that even in winter, the total capacity is about double what is required,

Other specifications:

Steam pressure	39 kg/cm^2	
Steam temperature	450°C	
Coal combustion	13 t/hr/unit	
Coal used	Mongolian-produced	50%
	Russian-produced	50%
Coal calorific value	3,200 - 4,300 Kcal/kg	
Boiler efficiency	Design value 88.9%	

(2) Steam and Hot Water

Steam is used in the molybdenum process of the mineral processing plant and aside from this application, it is used as hot water for air conditioning. The heat demand in summer drops to only one-third or one-fourth of its peak value in winter. (Please refer to Figure 45 and 46.)

(3) Diagnostic review

Fig. 45 HEAT ENERGY CONSUMPTION(1992)

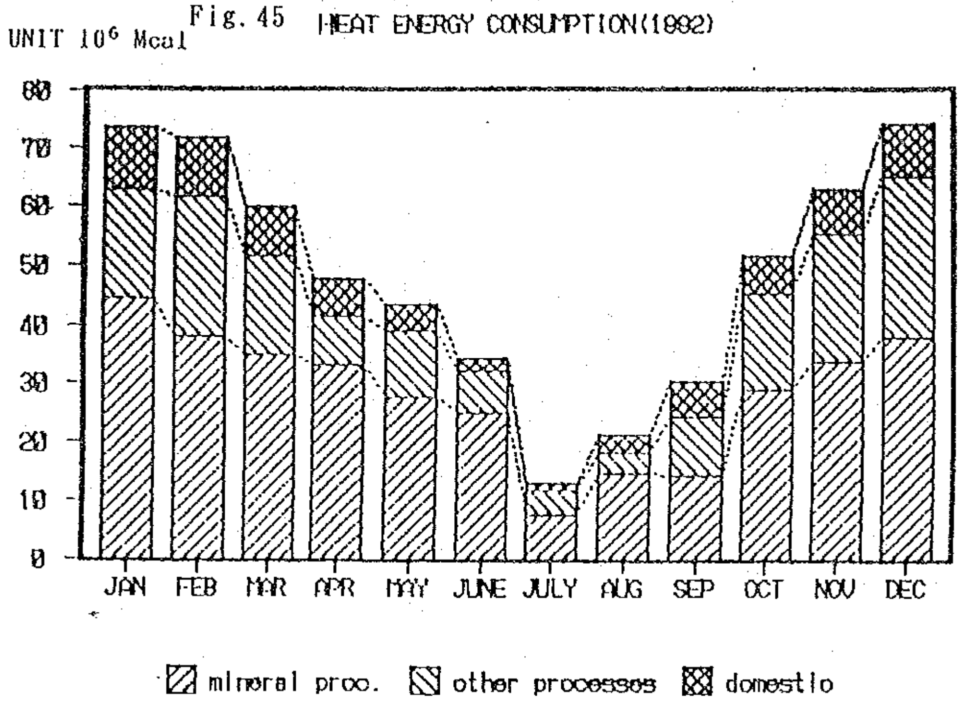
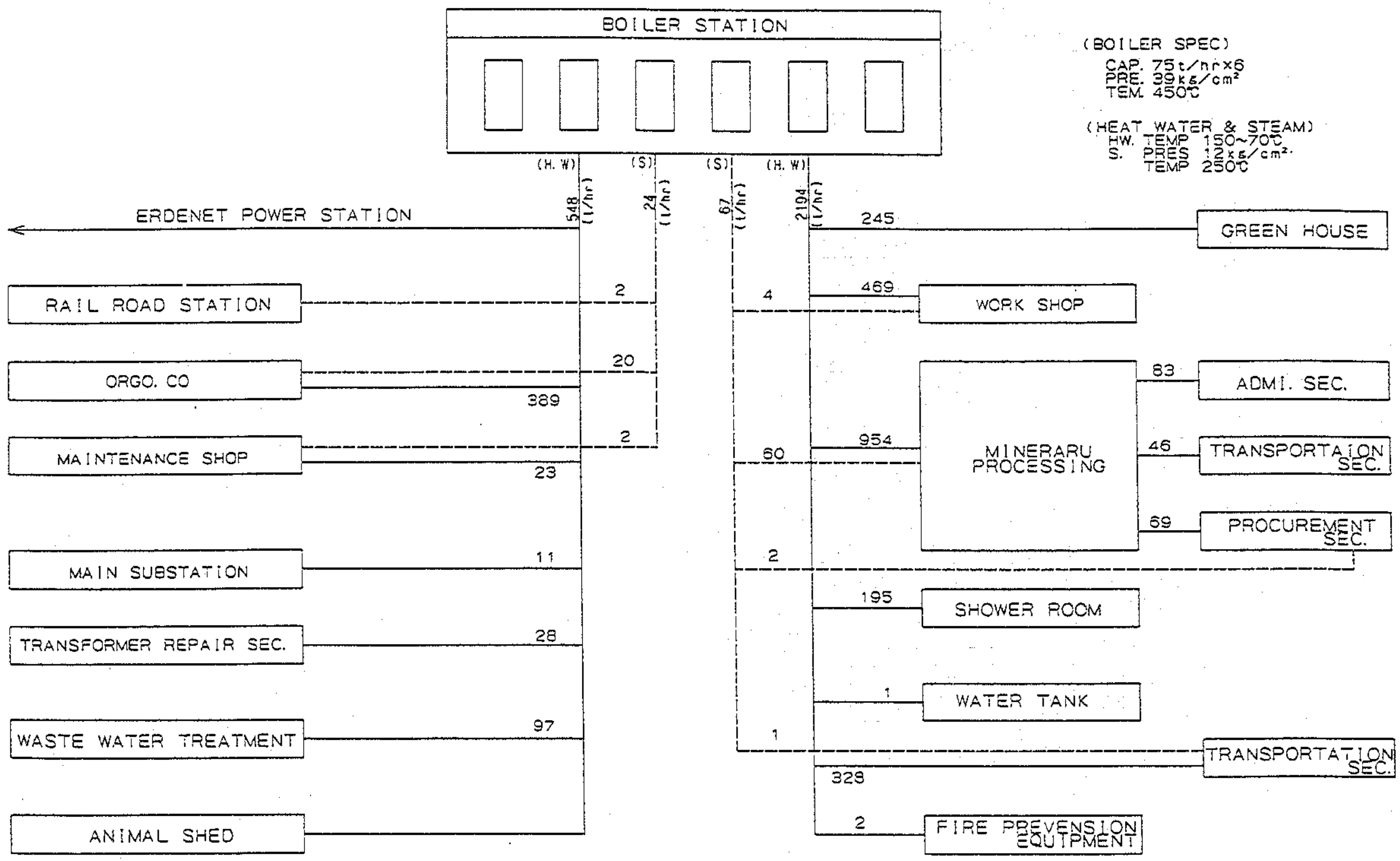


Fig. 46

HEAT WATER (HW.)&STEAM(S) DISTRIBUTION DIAGRAM (THE ERDENET MINE.)



—Although there is a problem of regular maintenance for the spare capacity of the boilers, if it is done during a period other than winter, there will be not actual change in this spare capacity. A program for power generation using this spare capacity will be referred to in a separate section.

—The boiler is a forced circulation type equipped with the air heater and the feed water heater which can recover low temperature heat energy resulting in high efficiency.

The designed gas temperature at the outlet of the boiler is as low as 145°C but due to the low sulfur content in the used coal, there is not so much problem of low temperature corrosion.

—The boilers were built 14 years ago and the steam heating pipes are corroded requiring replacement of some parts.

—Steam and hot water are distributed over a large area, being piped to 17 blocks and the longest pipe extends for 1.3 km.

The heat loss from the pipes, calculated from the specifications of pipes and insulation is 1% or less at most which is a small value.

—Instruments which were installed at the time of plant construction are still in use and becoming deteriorated. It is necessary to upgrade these instruments when steam is to be supplied to the power generators which means that they have to be renewed almost totally.

4-4-3 Water

(1) Water Intake

Water from the Selenge River, 60 km from Erdenet Mine, is pumped from a well and there are three pumping stations along the route to pump up the water. The water is used for both industrial purposes and as potable water. It is distributed via tanks to all plants, offices and city of Erdenet.

Water pumped per hour	2,400 tons
Pump head	610 meters
Pipeline	Diameter 800 mm, 2 pipes buried 3.5 m under ground
Electric power consumption	Ave. 10,000 kW

The electric power consumed accounts for about 11% of the total consumption of the mine.

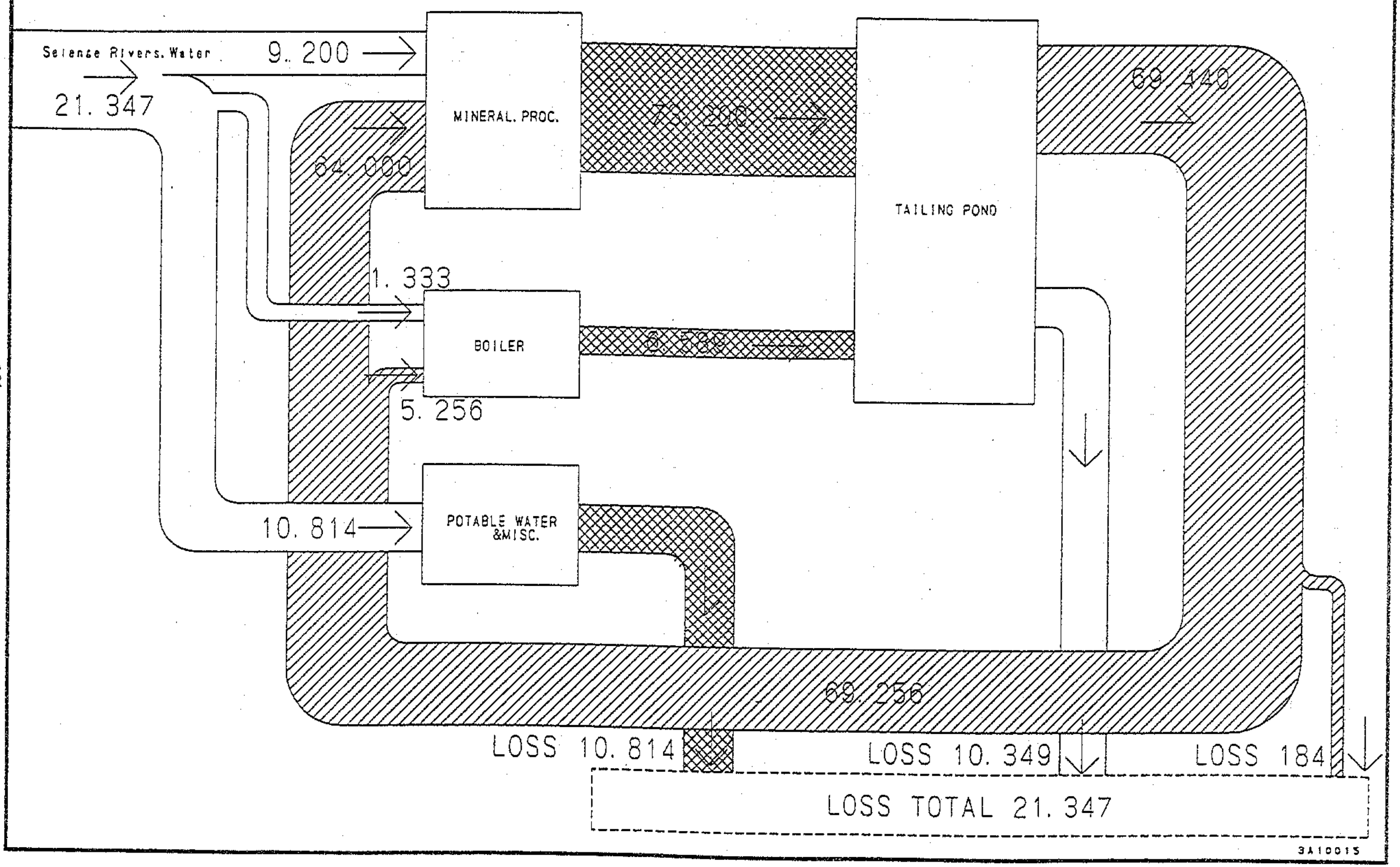
Quantity of water supplied to Erdenet city for local consumption is about 50% of total quantity. (Fig. 47)

(2) Recycled Water

Tailings and other water used in mineral processing plant is sent to the tailing pond where solids are settled. After settling, both the supernatant and percolated water are recovered for reuse in mineral processing plant.

Water quantity per hour	7,800 tons
Head130 meters	
Electric power consumption	Ave. 6,000 kW

Fig. 47 WATER BALANCE OF ERDENET MINE (1000m³/y)



The electric power consumption accounts for about 7% of the total electric power consumption of the mine.

(3) Effluent Treatment

The total quantity of water treated per day is 30,000 tons of which those from the mine is 5,000 tons and the remainder comes from the city.

(4) Diagnostic review

—A significant proportion (18%) of the electric power consumed by the mine is used to pump water which has important implications both for planning future electric power supply and cost. By the increase in quantity of ore treatment, the water consumption is forecast to increase and by the start of operation of the tailing pump in near future due to higher elevation of the dump yard, this proportion of the electric power consumption will increase.

—The possibility of using the underground water has been studied. If enough quantify of underground water is available nearby, the pump head will be less than one-third of that from the Selenge River which means that only one-third of electric power will be required to transport one ton of water. The more the underground water is used instead of water from Selenge River, the electric power can be saved more than two-third for each ton of replaced water.

Further, to depend only on Selenge River which is 60 km away as a source of water will cause production stop and panic to the city life at the time of trouble.

For these two points, the quality and quantity of underground water should be investigated urgently to establish a means to secure water.

4-4-4 Communication and Measurement

—A cross-bar type telephone exchanger is used for in-plant telephone system but the lacking of parts is becoming significant and it can now no longer cope with the deterioration. Today, an electronic type digital exchanger is becoming popular and it is far more better in function and trouble frequency. Together with the lack of parts, it is now the time to replace the existing telephone exchanger.

Subscriber circuits of existing telephone exchanger 600

—The waiting time for long distance and overseas calls is long which disturbs the modernization program and it is therefore necessary to improve the system. The measure will be referred to in the modernization section.

—Radio system for ore transport trucks and other radio systems for administration and control are inadequate. Further, there is a problem of spare parts supply and should be improved.

—Most of the instruments now in use were installed at the time of plant construction and they are deteriorated. They should be renewed with the computerized instruments gradually.

4-5 Business Management

4-5-1 Outline

(1) Style of Management

Management of the mine is carried out by the National Mongol-Soviet Joint Mining and Refining Corporation. This company is a joint venture formed through an agreement concluded in 1973 between the former Mongolian People's Republic and the Union of Soviet Socialist Republics.

The bilateral agreement concluded in 1973 was revised in 1991, with an effective period of 12 years. Today, the company is managed in accordance with the revised agreement. The outline of the revised agreement is based on the principle of equal rights and obligations for both parties. Erdenet Mine has a large degree of autonomy. The mine is free to decide which customers to sell its products to, and for what prices. Furthermore, the agreement approves technical cooperation between the mine and a third country.

We have not obtained the details of the 1973 agreement. However, we assume that the revised agreement provides for the shift to a market economy and more strongly reflects the intentions of the Mongolians.

The main products of the mine are copper and molybdenum concentrates from the Erdenetiin Oboo orebody, which is currently being worked. In addition, the agreement also states that, if the Mongolians and Russians concur, the mine may carry out other operations, such as those involving its workshop, attached plants and welfare facilities and the development of resources (for example, the development of coal deposits).

As the overall governing body for the company, the Erdenet Mine Joint Committee was established. This committee has a total of 14 members: seven Mongolians (the head of the Department of Mines of the Ministry of Geology and Mineral Resources as chairman, the Ministry of International Trade and Industry, the Ministry of Finance, two members from the Ministry of Geology and Mineral Resources, the President of Erdenet Mine, etc.) and seven Russians (the senior vice-president of Erdenet Mine and six others). The committee meets once a year. This meeting closely resembles a general shareholders' meeting under Japan's company law.

(2) Managerial Issues

The mine was in continuous production for 14 years since it started in 1978 until 1992. Until 1990, production had been maintained almost as scheduled, and there were no management problems. However, production suddenly fell in 1991, and has not risen since. The mine has informed us that the causes are a shortage of machine parts and an inadequate supply of electricity. We have confirmed these factors for ourselves.

Mineral deposits total 2 billion tons, and exploitable ore 1.5 billion tons. The mine therefore has excellent prospects.

Regarding costs, the mine is extremely competitive compared to well-known copper mines around the world. Production costs therefore appear to be an excellent feature of the mine. (Refer to Fig. 48.)

Among future issues, the shift to a market economy will require the mine to respond to a totally new environment, including an increase in unit product prices, environmental issues and foreign currency matters. An important

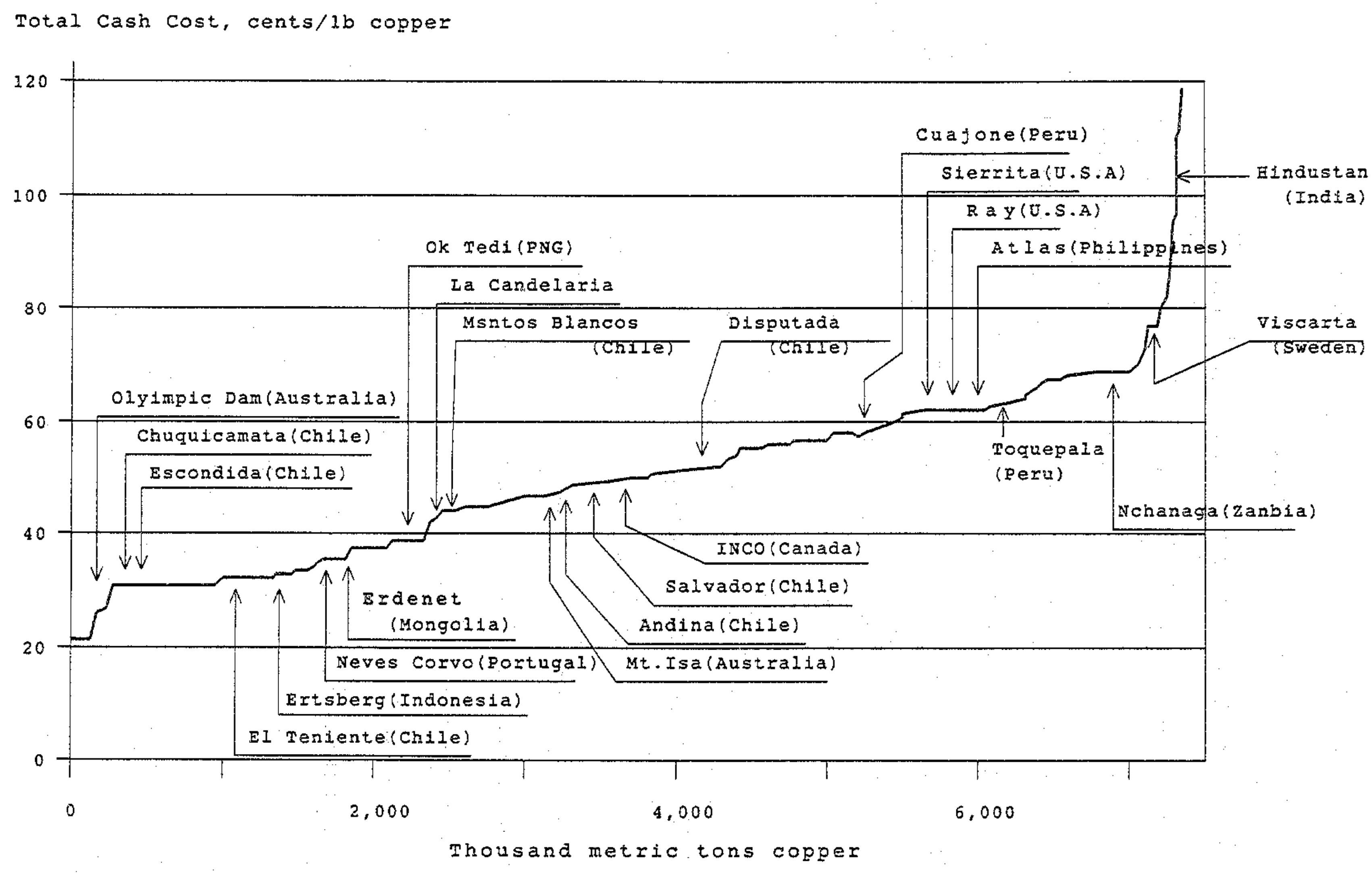


Fig 48 MINE PRODUCTION COST IN 1990

question, therefore, will surely be how the mine acquires managerial philosophies and strategies to rival those of other companies around the world.

As for the future level of operation, the mine has large deposits and could therefore expand. However, 15 years have already elapsed since the mine opened in 1978, and its original facilities need renovation.

Although Erdenet employed advanced technology when the mine opened, the technology is no longer satisfactory. The mine now needs more productive technologies and upgrading of facilities.

Upgrading facilities will require a large sum of money. Because of the state of the Mongolian economy, Erdenet Mine is unable to make independent decisions. Today, aggressive investment in Erdenet is needed in order to increase production, rationalize and make improvements. However, the mine must examine such matters as procurement and repayment plans for funds in accordance with the principles of a free economy.

4-5-2 Finance and Sales

(1) Considerations

A review of these matters, and a financial analysis in particular, suggests that attention needs to be paid to the following points, bearing in mind the special circumstances of Mongolia.

Firstly, balance sheets, income statements, and similar financial statements are prepared every year at the Erdenet mine and it can be said that basic management procedure is almost the same as in the West. However, the actual accounting method used there is different from those used in western countries (Refer to the next item). Therefore, considerable care must be exercised when interpreting financial statements.

Secondly, following the trade agreement with Russia and eastern European countries in 1990, prices began to be quoted in hard currencies. Market prices were used for the sale of concentrates and purchase of parts. Moreover, the tugrik has been devaluing significantly against the U.S. dollar. Therefore, any analysis of the financial situation or the local economy must take the rapid changes in the economic environment into account.

(2) Characteristics of accounting procedures

The balance sheet comprises assets and liabilities, whose totals balance. Under liabilities is a heading "Dorminsan". This seems to equate to the capital and profit brought forward accounts under a western accounting system. Fixed assets are recorded at purchase prices (before depreciation) and are not revalued. As for depreciation, the cumulative amount is recorded collectively under liabilities. Essentially, depreciation is calculated by a fixed percentage method, which uses a legally prescribed depreciation rate for each asset.

The Erdenet accounts display a characteristic feature of socialist accounting, namely, Savings Fonds. At Erdenet, there are three types of Fonds:

Award Fond: Equivalent to award payments to workers at the plant (paid monthly, and dependent on performance).

Social Security Fond: Equivalent to welfare-related payments such as social security for workers and funds for construction of sports facilities and apartment buildings.

Plant Development Fond: Part of the cost of machinery and construction at the plant comes from this fund.

According to the Erdenet Mine accounts, a portion (about 30%) of "net profit," obtained by subtracting total costs from sales, is saved to these funds. Most of the award funds and social security funds are equivalent to cost items under a Western accounting system. Thus, if we interpret the Erdenet Mine accounts in terms of Western accounting procedures, the net profit of the mine is reduced by the amount of these funds.

Sales
—) Total Cost
Net profit →
- Payment of Income Tax ····· 40%
- Erdenet fund savings ····· about 30%
- Retained profits (used for material cost, etc.) ····· about 5%
- Dividend (for Mongolia and Russia) ····· about 25 %

(*) Percentage varies slightly from year to year.

(3) Financial details

The capital specified in the bilateral agreement is about 500 million roubles. At the exchange rate prevailing when the mine opened (5.22 Tg/rouble), this amounts to approximately 2.7 billion tugrik. The capital shares are 51% for Mongolia, 49% for Russia, and these fractions will remain unchanged for some time.

The Mongolian government raised its share of the capital by borrowing the entire amount from the former Soviet Union, and most of the loan remains outstanding. The mine's future land and water charges, due from Russia to the Mongolian Government, will be offset against this loan.

Taking depreciation into consideration, total assets on the balance sheet are about 10.3 billion tugrik (as of the end of 1992). This figure does not include the value of deposits or mining rights. The proportion of net worth (Dorminsan, current profit etc.), is about 65%, which represents a stable financial state of affairs. When we look at the assets, it is notable that the accounts receivable (uncollected funds) and inventory are rather large (each equivalent to six months' sales). Accounts receivable from the government is one of the major reasons for the large balance of accounts receivable—this issue will be discussed later.

(4) Results

Table 47 shows changes in the sales, total costs and net profit based on data obtained from Erdenet Mine. These are quoted in tugrik. To facilitate comparison, the bottom half of the table indicates changes in the results quoted in U.S. dollars when the amount is converted on the basis of the annual average dollar exchange rates used by Erdenet Mine for accounting. Examination of the changes in the dollar figures reveals poor financial performance from 1991 onward.

However, profits are generally stable. The net profit shows figures before savings of funds. Taking this into consideration, it is still apparent that the mine is producing a profit each year, reflecting the high net worth ratio.

Table 47 Changes in the Results of Erdenet Mine

	1987	1988	1989	1990	1991	1992
(in 1,000Tg)						
Sales	840,617	814,543	774,646	806,544	582,846	4,582,215
Total cost	500,873	493,875	449,315	479,068	342,875	1,932,647
Profit (*)	339,774	320,668	325,331	327,476	239,971	2,649,568
Conversion (Tg/US$)	2.99	2.99	2.99	2.99	4.91	33.75
(in 1,000US$)						
Sales	281,143	272,422	259,079	269,747	118,706	135,769
Total cost	167,516	165,176	150,273	160,223	69,832	57,264
Profit (*)	113,627	107,247	108,806	109,524	48,874	78,506
Profit ratio	40%	39%	42%	41%	41%	58%

(*) Profits before Erdenet fund savings and tax
(Source: Erdenet internal materials)

(5) Liquidity Position

The liquidity position at the Erdenet mine is extremely tight, and this has affected the purchase of parts quoted in U.S. dollars. It is considered to be the prime reason for the decline in production starting from 1991 together with the shortages of electricity. One of the other reasons for the worsening liquidity position is certainly the problem of the funds tied up in inventory mentioned earlier—this issue will be discussed later.

The government of Mongolia demanded 55% of the foreign currency which Erdenet Mine obtained (an obligation to convert their foreign currency into tugrik at the official rate) in 1992. However, the mine was unable to pay for parts quoted in U.S. dollars with the 45% of foreign currency it can use at liberty. Furthermore, as of March 1993, some of the tugrik which the Mongolian government owed to Erdenet Mine in exchange for U.S. dollars had not been paid. As a result, in the financial statements for fiscal 1992, the Erdenet mine was also facing shortages of locally-denominated funds, which led to the nonpayment of electricity charges. In 1993, the distribution proportion of the foreign currency obtained changed to 48% for the government (55% in the previous year) and 52% for Erdenet. This means efforts were made to solve the above problem.

(6) Shortage of Liquidity

This is not a problem of Erdenet Mine so much as of the bankers with whom the Mine has business relation. The Mine's requests for cash are frequently not met. For example, in Mongolia, employees are paid their salaries in cash. However, the total monthly wage bill at Erdenet Mine is a huge sum. The Mine's bankers are unable to supply enough cash, leading to a situation in which the Mine has been unable to pay its employees in full (as of June 1993).

Erdenet Mine's external loans account for only a few per cent of its total assets, and leave room for further borrowing. However, domestic banks lack the capacity to meet the Mine's sizeable demand for funds.

(7) Sales

① Sales results

Please refer to the Table 6, showing the results of shipments by country set out in Chapter 3 (Overview of Erdenet Mine), for past results and 1993 forecasts. According to the Commercial Operations Division, commissioned refining produces higher profit margins than sales of concentrate, and is therfore expected to increase in the future. Erdenet Mine hopes to look into the possibility of commisisioning the refining to a third party such as South Korea, although it is geographically distant, if the conditions agree.

The Commercial Operation Division is responsible for sales and marketing. The division employs seven full-time staff. In addition, the division maintains one representative in each of Beijing, Kazakhstan and Moscow, where they are also responsible for procuring materials.

② Contracts

Contracts consist of long-term contracts and short-term spot contracts. The conditions in the contracts concluded with Russia and China specify delivery up to their national borders free on board, while the contract with Japan specifies cost, insurance and freight (CIF) to Japanese ports. Sales to Russia now come under the international conditions for ore sales. Arsenic penalties are the same as those for Western countries.

③ Transport

As Erdenet Mine is inland, the problem of transport has a significant impact on sales. The products shipped to the former Soviet Union are first put into an iron pot (weight 400kg) and then loaded on to an open freight train for shipping. One freight train can take 14 or 15 pots. As these pots belong to Russia, Erdenet Mine does not need to pay for them. Products shipped to China are transported in vinyl bags (*frecom* bags). These bags are reloaded into at Erlianhaote. Erdenet Mine pays the reloading charges to Ulaanbaatar Railways. Shipments to Japan can be made through one of two routes, either via Russia or via China. There is a risk that some of the products will be lost or that impurities may be mixed in during reloading at either Tianjin or Wanino ports.

In terms of freight, shipments to Russia are more economical. Goods shipped to China require the payment of reloading costs while shipments to Japan attract fairly high freight charges (the contract is concluded based on CIF at Japanese ports) and therefore work to the disadvantage of Erdenet Mine.

4-5-3 Procurement and Inventory Control

(1) Shortage of Materials

Most raw materials and equipment used at Erdenet Mine are imported. Only a small quantity of materials and equipment, such as coal and lime and construction materials, including lumber and bricks, are obtained domestically.

The Equipment Supply Division procures materials after collating requirements from each section. Most of the machines currently used came from the former Soviet Union. Erdenet Mine currently procures about 85-90% of its requirements from Russia. However, the mine has been obtaining materials and equipment from third parties such as China over the last one or two years. The branches in Russia and China make a purchase on receiving instructions from the head office. About US$ 100 million of supplies are required each year. However, a shortage of funds does not allow Erdenet Mine to purchase all the materials and equipment it needs. The Financial Division reports that about US$ 20 million in foreign currency was spent in purchasing materials and equipment in fiscal 1992.

After receiving orders from each section, the Machinery Division, which controls the inventory, checks the stocks in hand. The Equipment Supply Division then determines the quantities to be purchased. If funds are limited, as described earlier, the Financial Division and the Equipment Supply Division will together decide the revised quantities to be purchased. The priorities accorded to products on the order list are determined company-wide at management level. Materials and equipment whose shortage would, otherwise lead directly to a fall in output are given highest priority. These products include excavators, mill pumps, explosives, tires, dump trucks, gasoline and pig iron for use in the foundry.

② Procurement Method

As said earlier, most purchases are made from Russia. A single order is placed each year for each item. One reason for this purchasing method is that the Russian supplier requests Erdenet Mine to order once a year. Another reason is that the number of items to be purchased totals between 18,000 and 20,000 a year, and the companies from which the purchases are ultimately made number about 150. It is administratively impossible to make purchases more flexibly.

Erdenet Mine places an order in about March each year, and deliveries are made in about December. However, goods ordered frequently do not arrive on time because of suppliers' difficulties.

③ Inventory Control

As stated earlier, the inventory at Erdenet Mine reaches a value of about six months' sales. The inventory includes only small quantities of products. A large part of the inventory consists of materials and equipment. Erdenet Mine explains that the rapid increase in the value of the inventory stems largely from increases in unit prices rather than from increases in quantities held. However, it is difficult to judge how much effect this inventory has. December, the month when financial statements are made, coincides with the period when deliveries are made and is the month when the inventory grows largest. The large inventory of components seems to be putting pressure on the company's cash flow. It appears that the inventory also includes dead stock, namely non-performing assets.

4-5-4 Organizatin and Personnel and Labor Administration

(1) Staff Structure

Figure 5 shows the organization as of June 30, 1993.

Reflecting the nature of the joint venture agreement (capital ratio 51:49), almost equal numbers of staff from Mongolia and Russia hold senior executive and managerial positions.

One feature of the organization is that technical staff are located in the major production line divisions and sections. This arrangement is thought to resemble a line management system in western nations. However, the production division has a strong say in day-to-day administration, and technical staff are only in charge of planning, implementing comprehensive adjustments and gathering materials.

Divisions and sections have a diverse range of functions. When we look at the company as a whole, however, it is clear that some of these functions overlap.

Under the joint venture arrangement, detailed consideration is paid to the welfare of Russian employees and their families. They are directly administered by Russian senior management.

The mine employs about 6000 workers. This is quite a large number for a mine of this size. (Refer to the Table 48 "Comparison of the Number of Employees in the Copper Mines in the World and Erdenet Mine.")

(2) Personnel and Labor Management Control

① Personnel

Employment and dismissal of senior management, engineers, special staff

Table 48

Comparison of the Number of Employees of World Copper Mines and Erdenet Mine (1990)

Outline	Unit	La Caridad (Mexico)	Osland Copper (Canada)	Cajone (Peru)	SierritaTwin Buttes (U.S.A.)	Chuquicamat a (Chile)	Sar Chesmeh (Iran)	Erdenet (Mongoria)	Description
Amont of possessed ore	million ton	947	104.6	216.0	421.3	2,922.0	441	1,678	
Cu grade	%	0.47	0.36	0.87	0.34	0.81	1.12	0.49	
Amount of processed concentrate	1000 t/year	28,391	18,144	15,899	34,000	49,763	9,000	18,657	Actual results
Amount of ore and waste mined		44,973	40,642	32.589	75,999	187,763	18,000	35,055	
Stripping rate	%	0.6	1.2	1.1	1.5	2.8	1.0		
Grade of crude ore	%	0.72	0.36	0.82	0.41	1.39	1.0	0.826	
Recovery rate	1000 t/year	79.4	84.4	86.6	85.5	86.0	88	80.94	
Amount of concentrate	%	528.8	228.0	394.2	407.2	1,714.3	297.0	407,543	
Grade of concentrate	1000 t/year	30.5	23.9	28.7	26.5	34.7	32.0	30.41	
Copper production		157	55	128	134	722	102.0	123,933	Copper content in concentrate
By-product									
Au	kg	—	970	—		489	287		
Ag	t	69.5	15.1	35.1	29.6	130.0	15.8		
Mo	t	1,942	2,395	1,656	7,107	9,331	2,250	1,978	
Employees									
Mining	persons	651	265	850	450	3,200	600	408	
Mineral processing	persons	583	128	400	400	1,100	500	1,006	
Engineering	persons	(S 902)	55	—	—	—	(S1,200)1,000	2,034	S is employees at smelter, including managing job etc.
Managing	persons		124	950	—	—	2,700	2,322	
Total	persons	2,136	572	2,200	1,126	10,766	6,000	5,770	
									Costs for net copper
Costs									
Stripping	¢/b	3.4	19.5	9.9	13.8	9.8	3.5		
Mining	¢/b	5.8	15.8	9.0	9.4	3.5	3.5		
Mineral Processing	¢/b	14.7	30.0	20.3	30.8	8.2	11.8		
Others	¢/b	5.0	6.5	4.0	6.1	6.5	2.5		
Total	¢/b	28.9	71.8	43.2	60.1	28.0	21.3	35	

and Russians are decided by the Human Resources Department, while employment and dismissal of ordinary workers are decided by each section according to a personnel allocation plan, depending on needs arising from operations.

The criteria for employment and dismissal of Russians are set on the basis of the laws of Mongolia and Russia and of the employment agreement for the joint venture.

Foreigners working at the mine are exempt from immigration regulations and enjoy special privileges regarding taxation, holidays and so forth.

② Labor Conditions

Labor conditions for Mongolian employees essentially conform to Mongolian labor law and other employment regulations.

③ Labor Union

The employees have formed the Erdenet Labor Union; about 3000 employees are members. They also have an organization called the Federation of Free Unions, but it is rather ineffectual.

The Erdenet Labor Union is a modest union, with the following policy (source: Mr. Enebisi, chairman of the Union).

—The Union will cooperate in updating technology.

The Union expects greater safety for workers through modernized technology. The Union will cooperate in improving efficiency.

—The Union will act as a leader in training workers.

The Union ensures that its members study, so that they will not be left behind.

—The Union does not want confrontation with the company, but takes a cooperative stance.

However, the Union considers guaranteeing the rights of workers to be its highest responsibility.

Only one employee works full-time for the Union. Membership fees are 1% of basic salary. The Union also participates in international groups; for example, in Mongolia, new labor union and reconciliation laws have been promulgated. It must be noted that when information from western nations enters labor circles, changes will take place in the organization of the Union.

④ Wage System

—Wages are determined on the basis of a standard rate for the job plus additional pay based on job evaluations. Management and employee wages do not differ significantly. In fact, allowances for special operational conditions may result in production workers receiving higher wages than white-collar workers.

While it is not a cast-iron rule that white-collar staff must always receive higher wages than those directly involved in operations, from the point of view of macroeconomic efficiency the wage system at Erdenet merits review.

—Erdenet Mine is innovative in that, in addition to the minimum wage, the number of dependents a worker supports is taken into consideration in determining a wage that will allow the employee to maintain his or her household.

—Revising the wage system will affect many other matters, and therefore should be handled with care.

However, based on the workings of a market economy, it is appropriate that there be differences between wages based on job evaluation.

⑤ Job training and education

—Emphasis is placed on job training, and education levels are high.

—Qualification tests are incorporated into skill training. We can see the results of maintaining a certain level of skills.

—University graduates are in principle eligible to become managers and engineers. Erdenet Mine secures its human resources through international study programs and a scholarship system. As the number of workers studying in Russia is decreasing, it is necessary to shift these workers to other language areas, for example western countries. However, this will be difficult unless the Mongolian educational system changes fundamentally.

Erdenet Mine must make efforts to maintain capable human resources, including Russian senior engineers.

(3) Quality Control

The Quality Control Division is responsible for checking the quality of concentrates, products of the Mine (including those sold to other companies) and materials purchased (coal, lime etc.).

The division focuses on statistical analysis and dissemination of information concerning the results of quality checks. The division has yet to focus on drawing up measures to maintain quality.

What is most important in maintaining quality is the production processes;

organizational control should be enhanced in these production processes.

The Analysis Division must also improve its facilities and raise its technical level.

(4) Safety Control

—Accidents are few, given the scale of the mine's operations and its harsh environment. However, there are indications that problems concerning vocational diseases will arise.

As vocational diseases are not evident over the short term but become more frequent over many years, large numbers could be anticipated. This raises not only social issues, such as compensation, but also questions of future risks involved in management of the company.

Coniosis, pneumosilicosis and related diseases, as well as hearing difficulties, are already present.

4-5-5 Welfare

Welfare facilities are excellent.

The mine has a wide range of service functions in residential areas, as well as hospitals, cultural and rehabilitation facilities, sports facilities, recreational facilities and kindergartens. The mine has almost all the facilities normally found in a city. These facilities were established under the socialist system, and are still in operation today. The welfare provisions at Erdenet Mine are considered the best in Mongolia.

The company meets the costs of running these facilities. A special welfare fund manages the budget.

Consideration should be given to how the welfare provisions will change as individual workers, sense of value change over time.

4-6 Pollution Control and Working Environment

At present, the worldwide trend on environmental control has progressed one step from the environmental assessment to so called "sustainable development" which focuses on the essential of policy with a philosophy to promote development while maintaining the ecological system. (Please refer to Fig. 49.)

It is the responsibility not only of the Government of Mongolia but also of Erdenet Mine to maintain and preserve the wonderful natural environment left in Mongolia.

Erdenet Mine, which is a nonferrous metal industry handling the limited and unrecoverable resources and emitting hazardous materials should pay further strict attention to the environmental control measures.

However, it is already 15 years since the start of operation and there are signs of environmental pollution which require immediate countermeasures. The most important issue for the Erdenet Mine is to invest sufficient cost to the environmental control and also to establish a competitive power in the international free economy markets.

For atmospheric and water pollution and present working conditions, we had an interview with the engineers in charge and staff personnel of Erdenet Mine. At the same time with the simple apparatus we brought from Japan, we took actual measurements as well as obtained actual operation data, specifications of related equipment and copies of related laws and regulations.

Further, there is a Green Peace movement and we interviewed not only the government authorities such as weather bureau but also people living in the surrounding areas.

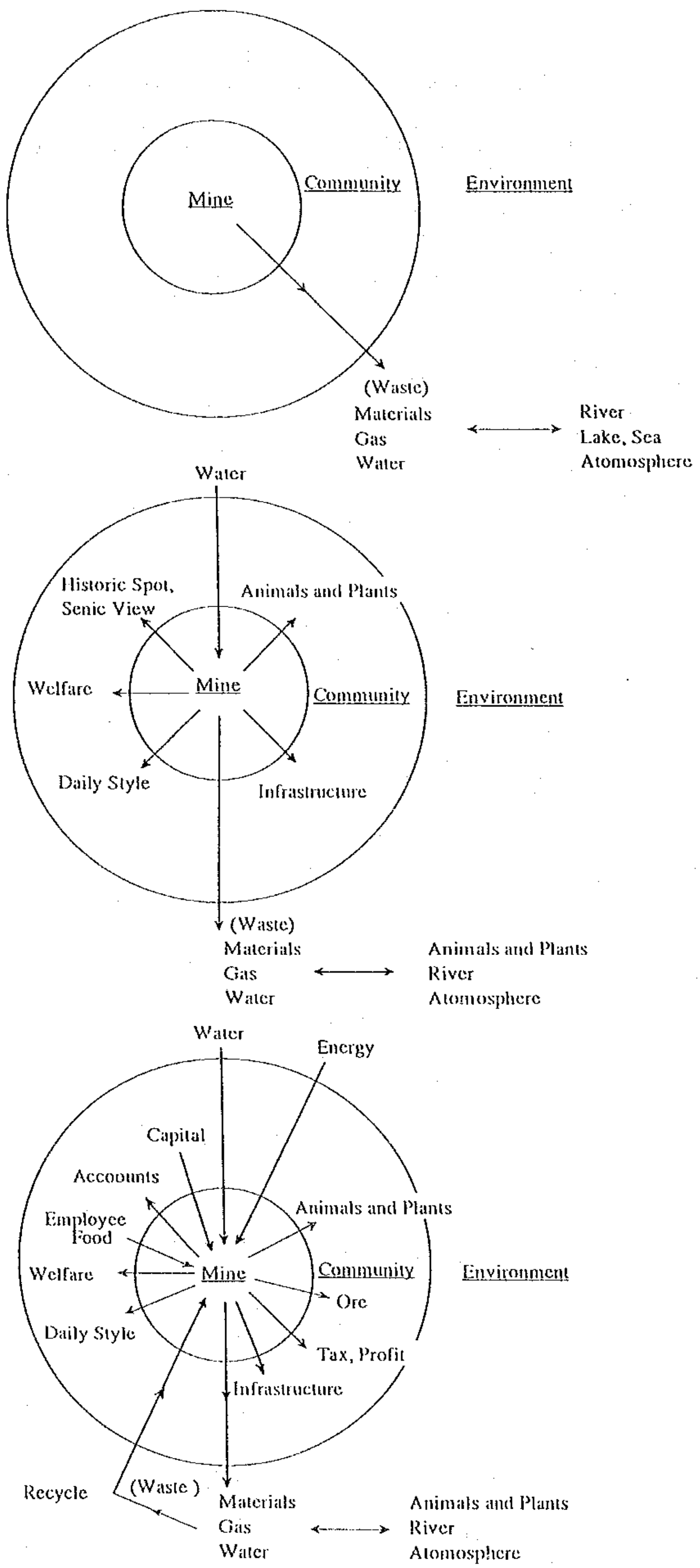
In this Chapter, the outline, result of investigation and foreseen problems of the pollution control of water and atmosphere as well as improvement of working environment are given.

Fig. 49 Policy Change on Anti-Pollution and Environmetal Control

Anti-Pollution
(Operation)
(~1970's)

Assessment for Environment
(Before Operation)
(1980's)

Audit for Environment
(1990's)



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4-6-1 Air Pollution Control

The section in charge of the air pollution going outside of the plants of Erdenet Mine is the Energy Department.

We requested the general manager and his staff to furnish us the data and information on discharged gas and further, we had a discussion on the present problems and countermeasures. We also visited the work sites and made measurements with a transfer of technology and gathered data. The necessary samples were taken and analyzed in Japan.

At present, the atmospheric pollution problems are the following three issues.

The characteristics of these problems are that they do not occur constantly but only when there is a trouble in operation or depending on the season of the year.

—Smoke containing fly ash from 6 units of boilers (via 100 meter high stack).

—Black smoke from copper concentrate dryer (heavy fuel oil combustion).

—Dust generation in March to May of each year from mineral processing tailing pond.

The result of investigation on the sources and problems in comparison with Japan are described below.

1) Boiler exhaust gas

In the case of boiler burning only coal, the sulfur contained in coal and ash are mixed in the exhaust gas.

The coal used by the mine contains 0.7% at its maximum S which is low