JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

THE ERDENET MINE
MONGOLIA

# REPORT
# ON
# STUDY OF THE ERDENET MINE MODERNIZATION AND DEVELOPMENT PROGRAM

## VOLUME Ⅲ
## RECOMMENDATION ON THE COPPER SMELTER CONSTRUCTION

December, 1993

MITSUI MINERAL DEVELOPMENT ENGINEERING CO., LTD.,
TOKYO
(MINDECO)

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Contents

## 1. Preface

Erdenet Copper Mine in Mongolia has resources and facilities to produce 120,000 tons/year (as copper metal) of copper concentrate and at the moment, this copper concentrate is exported. This export bears an important role in national economy of Mongolia to earn foreign currencies.

As shown in Table-1, the world-wide consumption and production of copper metal is gradually increasing although they are not as high as the economic growth which is about 4%. The price of copper metal varies from time to time depending on the supply and demand balance, social problems (labor strikes, war, etc.) and other causes but in general, it is deemed to rise together with the prime commodities.

It is natural for Mongolia to consider a means to add higher value to the resources produced in the country, for example, to produce copper metal ingots, i.e, to construct a copper smelter. Based on this concept, "Report" on Development of Copper Industry in Mongolia (hereinafter referred to as the "Report") was prepared already in 1992 under the instruction of the Government.

This report contained herein refers to the "Report" with the approval of the Government of Mongolia and is based on the discussion with those who prepared the "Report" as well as concerned personnel. A referential opinion on a possibility and economy of construction of a copper smelter as a part of the modernization program of Erdenet Mine based on a review from several different aspects is explained herein.

Table 1 Forecast of world copper supply, demand and price

| Year | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|
| Copper Consumption ,000 tons | 8,969 | 9,050 | 9,350 | 9,700 | 10,050 | 10,300 | 10,550 | 10,750 |
| Ore Prod. (Net) ,000 tons | 7,411 | 7,550 | 7,800 | 8,050 | 8,350 | 8,600 | 8,850 | 9,075 |
| Ingot Prod. ,000 tons | 8,539 | 8,800 | 9,050 | 9,400 | 9,700 | 10,000 | 10,350 | 10,550 |
| Stock ,000 tons | 862 | 912 | 890 | 860 | 810 | 760 | 790 | 820 |
| Producer's price US$/ton | 2,352 | 2,285 | 2,315 | 2,460 | 2,675 | 2,790 | 2,965 | 3,070 |
| Market Price US$/ton | 2,465 | 2,356 | 2,315 | 2,375 | 2,500 | 2,505 | 2,560 | 2,550 |

Note : Statistics of West is the basis.

## 2. Summary of Recommendation

Construction of copper smelter in Mongolia may be possible in near future although the production capacity and the construction schedule are not fixed at the moment.

The "Report" was reviewed from different point of view based on such premises and the recommendations we can make are as described below.

Looking at domestic point of views,

(1) It is unavoidable and correct decision to freeze the copper smelter construction project at the moment from financing and pollution problems.

(2) We believe it is necessary to prepare for the promotion of the project after observing and studying well the trend of improvement of domestic economical situation as well as the changes in surrounding international circumstance.

(3) It is estimated that Erdenet Mine has maximum production of 120,000 tons/year (Cu net) but this quantity is not sufficient to supply to a copper smelter of justifiable production capacity.

It is therefore important to consider development of other copper mine taking into account the production expansion of the smelter in future.

(4) It is necessary to increase the number of smelting engineers for future operation and research and development as well as training should be conducted. Nothing could be done without adequate number of qualified personnel.

(5) A measure to cope with the sulfur dioxide gas emission is important with the pyrometallurgical smelting. A large scale smelter creates an apprehension for atmospheric and water pollution in wide area. It is not advisable to promote the project without harmonization of industrial development and the

environmental preservation.

(6) It is necessary to have a close contact with the smelters of western countries to gather information on technology, financing and cost.

Looking at foreign situations, the following could be recommended.

(1) The project has influence not only to the economy of Mongolia alone but to the former USSR which has strong relation with the non ferrous mining industry of the country and it is necessary to watch the changing trend of Russia for future 5 to 10 years. There may be a possibility of decrease in concentrate sales to Russia due to pollution problem and other reasons.

(2) Recently, a suspension or giving up of new copper smelter construction (for example, Mitsubishi in USA, Indonesian project, Thailand project, etc.) is noted around the world. The reason why they were suspended or stopped should be noted well. Due to the problem of location, there are more expansion projects of existing smelters. It seems that the trend is to select expansion which is less in construction cost and more effective.

(3) It is also necessary to have technical interest in the hydrometallurgical smelting process (example: SX-EW Process) or so called stackless smelter, to determine the future trend of smelting process. There is a forecast saying that one third of the future production of copper ingots will be by SX-EW Process.

The estimated copper consumption in Mongolia is only about 2kg/men/year totaling to domestic demand of only 5,000 t/year and if so, it may be possible to establish a production system to meet this demand. It may be possible to enter into copper production industry from this scale.

(4) Mongolia is located adjacent to East Asian countries which have a

possibility to grow into copper metal and its byproducts market. This means the market condition which is one of the location conditions of copper smelter is advantageous. If the net income from sulfuric acid sales can cover its recovery cost, the profitability will be much improved. But the problem is that the sulfuric acid market is always in over supply condition.

Considering the above conditions, it is necessary to have a financing program for the copper smelter construction project as well as to have a feasibility study report which shows financial and economical effects. We recommend such feasibility study to be prepared by an organization with sufficient technology and experience.

3. Exchange of Information with the Government Authorities and Engineers and Relevant Documents

3-1 List of those who attended in exchange of opinion on development of copper smelter program

(February to March, 1993)

(1) Mr. N. Algaa, Senior Metallurgist in charge, Ministry of Geology & Mineral Resources

(2) Mr. Tsogdsaikhan, Senior Metallurgist in charge, Erdenet Mine (Workshop)

(3) Mr. Otgonbileg, General Director, Erdenet Mine

(4) Mr. T. Oyunbileg, General Director, Dept. of Mines, Ministry of Geology & Mineral Resources

(5) Mr. Dambadarjaa, Beijing Concern, Erdenet Mine

(June, 1993)

(1) Mr. Dambadarjaa, Beijing Concern, Erdenet Mine

(2) Mr. N. Algaa, Senior Metallurgist in charge, Ministry of Geology & Mineral Resources

(3) Mr. Tsogdsaikhan, Metallurgist in charge, Erdenet Mine

Mr. Ts. Laaganjav, Metallurgist in charge, Erdenet Mine

Mr. D. Tsogdkhangai, Metallurgist in charge, Erdenet Mine

Mr. B. Badarch, Metallurgist in charge, Erdenet Mine

3-2 Documents furnished by Mongolian authorities to Japanese survey group for development of copper smelter program

(1) "Report" on Development of Cu Industry in Mongolia (1992)

(2) Technical and Economical Background on Copper Smelter Development Program

3-3 Referential documents submitted by the Japanese survey team on development of copper smelter program

(1) Abstract on Update Cu Smelter Process including Wet-Process

(2) List of Copper Pyro-Smelter and Refinery with Production (x 1,000 t/y)

(3) Comparison of Copper Smelting Process

(4) Technical Information on Copper Smelting for Erdenet Metallurgist

a. Recommendation of Construction Program of Cu Smelter

b. Reference Drawings for 100,000 t/y Cu Smelter

c. Organization, Manning Schedule for 100,000 t/y Cu Smelter

d. Estimated Materials and Utilities for 100,000 t/y Cu Smelter

(5) Technical Information on Copper Metallurgy for Erdenet Metallurgist

a. Energy for Cu Smelting

b. Arsenic Removal form Cu Concentrate

c. Hydro-Metallurgy

## 4. Outline of "Report on Development of Copper Industry in Mongolia"

### 4-1 Purpose and Scope of "Report"

The Report was prepared by the Working Group assigned based on Resolution No. 119 of the Government of the People's Republic of Mongolia issued on November 23rd, 1991 aiming to establish the government policy on the exploration, mining and mineral processing of copper resources and construction of copper smelter.

This Working Group was organized by about 15 people including government concern, engineers of Erdenet Mine and economical analysts and the Report was prepared in about half a year.

The Report covers a wide range including domestic distribution of resources, comparison of both local and overseas mining and mineral processing technologies, production estimate up to the year 2005, future development of copper smelter and copper fabrication plants, recovery of byproducts and valuable materials, and financing.

We reviewed the documents furnished to us and we think the Report is just a preliminary report on the copper industry in Mongolia and not as detailed as to become a Master Plan of a country.

### 4-2 Basic Design of Copper Smelter (Scheduled to start operation in 1996)

(1) Production capacity (utilizing Outokumpu Process of Finland) 100,000 tons/year as copper cathode (99.99% Cu)

(2) Molybdenum production

Mo metal or Mo based alloy production

(3) Copper oxide ore treatment (SX-EW: Solvent extraction-Electrolytic winning) to produce copper cathode

(4) Pyrite concentrate treatment

Sulfuric acid production of 636,000 tons/year and production of copper slime which includes 1,080 tons/year of Cu and 1.37 tons/year of Ag.

(5) Production of 450,000 tons/year of phosphoric acid fertilizer containing 36% $P_2O_5$ utilizing phosphorous ore from Muron Phosphor Mine and sulfuric acid produced in the above items (1) and (4).

(6) Copper fabrication plant of 9,000 tons/year capacity.

(7) Other modifications and infrastructures

4-3 Rough Estimation of Investment Cost

| | |
|---|---|
| (1) Rehabilitation for Erdenet Mine | 42.1 Mil. US$ |
| (2) 100,000 tons/year copper smelter | 450 |
| (3) 9,000 tons/year fabrication plant | 3.2 |
| (4) 450,000 tons/year fertilizer plant | 50 |
| (5) Development of Muron phosphorous mine | 60 |
| (6) Railway construction between Erdenet and Muron | 438 |
| (7) Power line installation between above | 121 |
| (8) Geological survey | 3 |
| Total | 1,167.3Mil. US$ |

Provided, the exchange rate applied is 40 TG/US$, 1 exchange Rub/US$.

4-4 Simple Economical and Financial Analysis

4-4-1 Simple Economical Analysis

The simple economical and financial analysis was done applying the simple rate of return on investment, period of recovery method and the major results are as enumerated below. Provided that, this is not the overall analysis of the project.

(1) 100,000 tons/year copper smelter and refinery

| | |
|---|---|
| Investment | 450 mil. US$ |
| Profit | 66.4 mil. US$ |
| Recovery | 7 years |

(2) Pyrite concentrate treatment

| | |
|---|---|
| Investment | 75 mil. US$ |
| Profit | 3.4 mil. US$ |
| Recovery | 22 years |

(3) Chemical fertilizer plant

| | |
|---|---|
| Investment | 50 mil. US$ |
| Profit | 3.6 mil. US$ |
| Recovery | 14 years |

4-4-2 Financial Analysis

No specific financing method has been studied yet to finance the investment required for the construction but basic concept is to introduce fund from overseas. Aside from the aforementioned plan, a custom smelting,

investment to foreign (Russia) smelter, construction of refinery alone, etc. are also studied by comparing the advantages and disadvantages.

## 4-5 Problems Pointed Out

### 4-5-1 Problems Pointed Out in the "Report"

(1) Treatment of byproduct sulfuric acid

It is necessary to study not only pyrometallurgical but also hydrometallurgical process of copper smelting.

(2) Request toll basis smelting to the overseas smelter (Russia, Kazahstan). It is already done now.

(3) Study the possibility of requesting the overseas smelter for treatment of concentrate to produce blisters and construct refinery in the country.

(4) Invest in overseas smelter and construct joint venture smelter.

(5) When development of phosphor mine is not possible, it is necessary to study the importation of phosphor ore.

### 4-5-2 Problems Pointed Out During Discussion

(1) Vast amount of investment and way of financing.

(2) Treatment of byproduct sulfuric acid and production of phosphoric acid fertilizer. The phosphor mine of Muron is located in the national park and it is difficult to develop this mine.

(3) The development of smelter may have the possibility to accelerate environmental pollution.

(4) It is necessary to promote investigation of hydrometallurgical process which will not produce sulfuric acid.

(5) It is necessary to promote overseas collaboration for both technology and financing.

4-6 Appraisal of "Report" by the Government and Current Opinion

Taking into account the problems pointed out in the above paragraphs, we have received the following appraisal and opinion on the Report from the government and management of Erdenet Mine.

(1) The "Report" is an investigation report on the copper industry in the Republic of Mongolia and is not the one to be considered as a Master Plan.

(2) The "Report" is now under study by the authorities in the Government and it has not yet been authorized. However, it is understood and agreed for Japanese Survey Team to refer, comment and make recommendation on the "Report" for their investigation.

(3) The construction cost of the copper smelter is too large considering the present economic situation in Mongolia.

(4) Generally speaking, copper smelter is an environment polluting type plant in the sense of exhaust gas and waste water and this may accelerate environmental pollution.

(5) For the above reasons, this copper smelter construction program will be suspended for the time being and shall be reviewed when the economic situation turns better.

(6) Until such time, more advantageous and profitable method by sales of

concentrate or custom smelting shall be studied and prepare for the forthcoming investment.

## 5. Comment by Japanese Experts

### 5-1 Outline of Comment

There are only few experiences of actual smelting technology in Mongolia. This Report was prepared only with such minimal experience in smelting and with only few available information and it should be highly appraised.

However, it could not be considered as a Master Plan to base the national policy of Mongolia immediately. But it can be the basis and is quite useful for further detail study to be made in future. For the national project which requires vast amount of investment, such as this project, study based on more accurate and detailed feasibility study report is required.

### 5-2 Financing

Generally speaking, a capital cost for the construction of copper smelter is said to be 15 cents/lb to 20 cents/lb of copper produced. The justification of the amount 450 million US$ required for the construction of smelter should be studied in comparison with the other cases.

However, the total project of 1,167 million US$ which includes smelter construction, is on the same level as the GNP of Mongolia and it is several times the national budget, which means the figure is the one which can never be attained.

Once a copper smelter is constructed, a repair and maintenance service to maintain the operation becomes necessary and such related industries also have

to be brought up. For such industries, the financing has to be increased and this issue requires a careful study before deciding.

5-3 Environmental Influences

Compared with the mining which produces and treats crude ore, it is important for the smelting which is a down stream industry to take sufficient measures against emission of sulfur dioxide gas. Particularly, complete recovery of sulfur regardless of atmosphere, water and cost should be done. It has great influence to the environmental pollution and labor hygiene problems.

There are many cases all around the world where the government policy was too much focused on production and ignoring pollution control and now facing the situation where it has to pay an expensive bill for recovery of environment.

It could be said that the nonferrous metal smelting shoulders a "fate of an Environmental Economy."

The history of nonferrous metal industry in Japan after 1960's is a history of discord between production activities and environmental preservation and has overcome it with technical development and successfully maintained the present competitive power. Japan has accumulated abundant experience through critical sacrifices and as result, Japanese smelters can satisfy the most stringent environmental regulations in the world (recovery of 99.5% of sulfur).

In Mongolia, it is necessary to do sufficient assessment and employ most advanced pollution control and equipment when the construction of copper smelter is decided.

Further, the pollution of surrounding environment means destruction of living and working environment of the workers working in the area and such

construction will never be accepted by the people living in the area.

To establish a pleasant and safe working environment with the control of hazardous material emission means an evidence of a correct working activity.

### 5-4 Priority to Infrastructures

The Report points out that a large portion of investment should be allocated to this field giving priority to the maintenance of infrastructures and this should not be neglected.

Without a prior maintenance of roads, railroads and other transportation measures as well as communication facilities, the copper smelter cannot stand the competition in the international market after start of operation.

At the same time, energy, water and other utilities should also be installed and prepared in parallel to well organize the social basis in wide range.

### 5-5 International Collaboration

In order to materialize this large scale project, it is difficult to do it by Mongolia alone but requires foreign support on technology and financing.

For such purpose, it is necessary and collaboration with overseas firms from the stage of investigation.

Collaboration, particularly with the western countries who are looking for stable supply of copper concentrate may be effective.

It is important to materialize the project by supplementing each other between Mongolia whose major source of foreign currency is copper resources and

the western countries who are stable consumer of copper and both having benefits.

## 5-6 Collaboration with Copper Smelters in CIS

Originally, the development of this Erdenet Mine had a role to supply copper raw materials to the smelters in former USSR (Ural).

Even at present, it is supplying concentrate to smelters in Russia and toll basis smelting is done by Balksash Smelter (Kazakhstan). This situation may not be changed easily but in the future, it is necessary to have flexibility to increase and select more partners for collaboration.

As the democratization of eastern world is promoted, the actual situation of nonferrous metal industry in former USSR and east European countries, which were at that time hidden behind the curtain, became clear and its not so high technological level and poor product quality, meaning low international competitive power, are becoming problem.

Particularly, the omission of pollution control and almost no consideration for quality assurance are the points of problem.

For example, there is a problem of the copper cathode produced by custom smelting cannot satisfy the LME grade and cannot reach the international price level.

From this point of view, we have to recommend an investigation and review of the smelters in CIS.

## 5-7 Training of Smelting and Relation Engineers

It is necessary to start as early as possible the education of personnel related to the smelting.

It is never too early to have a group of able personnel.

We recommend to establish already at Ulaan Baatar or Erdenet Mine an independent "Smelter Department" and start the following pre-project works mainly by metallurgists.

(1) Investigation on present and future trend of overseas smelting technologies, particularly, research and development on hydrometallurgical processes

(2) Training in operating smelter and a small pilot test of smelting plant

(3) Investigation and test on the environmental pollution, automatic control of process, energy, etc.

The results of the above study can be well utilized for the sales of concentrate as well as for the negotiation of smelting conditions.

Unlike mine operation which is done under ambient temperature, copper smelting involves, high temperature, high risk, centralized mechanization, automation, continuous operation and highly polluting environment which require high control level of operation.

Therefore, it is noted that the smelter operation requires not only experienced metallurgists but also quite a number of engineers for mechanical, electrical, instrumentation, civil and building, pollution control and safety and hygiene in order to support the maintenance of facilities and high grade services.

## 6. Technical Recommendations

### 6-1 Production Capacity

The Report is based on the production of 100,000 tons/year of copper cathode.

In the world today, the ideal capacity from the economic point of view is said to be more than 200,000 tons/year but considering the fact that the project is to treat copper concentrate from Erdenet Mine, we believe the capacity mentioned in the Report is reasonable.

The reason for us to say so are explained below.

(1) As a first copper smelter (nonferrous smelter) in Mongolia, it has to exert its efforts into inexperienced new pollution control, acid treatment, etc. and it is easier to do so with a not so large scale.

(2) The proposed capacity meets the concentrate production (copper net) of 120,000 t/year from Erdenet Mine. Even if the development of Tsagan-Subraga and other mines are materialized, their production will be only to make up the fluctuation of Erdenet Mine and as a first smelter in Mongolia, the capacity of 100,000 tons/year seems reasonable.

(3) As content in the concentrate from Erdenet Mine is high to the extent of 0.3 to 0.20% and a special consideration and equipment are required for the removal of As. The smaller the scale is, it is better because the influence will be less.

(4) There is a case of the smelter with advanced process with the capacity of 90,000 tons/year, which is Harjabarta Smelter utilizing Outokumpu technology meaning that there is a case which is economically viable with such scale.

(5) Most of the existing smelters in developed countries started with a capacity

of about 100,000 tons/year and then expanded production by 150 to 200 % by modifications and improvements.

However, basic points for production expansion in future should be considered and included in design.

The bottle necks are the raw material handling, sulfur dioxide gas treatment, etc. and particular attention should be paid to the layout of the equipment to give enough rooms for future expansion.

If only the domestic consumption in Mongolia is to be considered, hydro metallurgical process such as SX-EW Process may be considered. It is said that a justifiable production capacity with this process is about 10,000 t/y.

## 6-2 Copper Resources Supply and Location of Plant

### (1) Copper concentrate supply

The special characteristics of copper concentrate from Erdenet Mine are that it contains small quantity of gold and silver which are sub-contents creating extra income while the arsenic content subject to penalty is 3 to 5 times higher than the normal concentrate. As a smelter raw material, it could be said that this concentrate is easy to treat except the high arsenic content. However, from the point of pollution control, it belongs to concentrate difficult to treat. The requirement on arsenic content by the western smelters is very stringent, such as less than 0.07% in Japan.

The mine life of Erdenet Mine is more than 30 years but considering a future production expansion, the ore reserve is insufficient to have own smelter. The development of nearby deposits and copper concentrate supply from the

southern Tsagan - Subraga mine should also be considered. To establish a combination of a mine and a smelter with competitive power, it is preferred to have more ore reserves.

(2) Plant location

There are two possible locations named in the Erdenet Mine area and the place about several kilometers east of the Erdenet mineral processing plant is selected as the first candidate. The conditions to determine the location of smelter depend on the transportation distance of utilities such as power and water, of concentrate and products, on the weather conditions such as wind direction, utilization of maintenance shop together with the mine, and other factors. From the economical point of view, to be located near the market for product metal ingot, market of byproduct sulfuric acid should be considered.

Final determination should be made taking into account the development of up stream and down stream industries from mine, smelter to fabrication should be considered with an integrated industrial complex in mind.

6-3 Selection of Process

When the scale of the plant is 100,000 tons/year production, the process should be pyrometallurgy under present technological standard.

The "Report" is based on the use of Outokumpu type flash smelting furnace which is said to be the most reliable in the world today and this decision seems to be reasonable based on the "Comparison of Copper Smelting Process" which we presented.

As a modified flash smelting furnace, an energy saving type with electrodes integrated in the furnace and without the use of a slag cleaning

furnace, which is operated at Tamano Smelter of Mitsui Mining & Smelting Co., Ltd. is also in actual commercial operation.

Other than these two, there are Mitsubishi Continuous Smelting Process, ISA Process, NORANDA Process which uses pure oxygen and other several smelting processes. Data and information on these processes have been presented to the metallurgists of Erdenet Mine for their study.

The information includes hydrometallurgical process which does not produce sulfuric acid as a byproduct.

### 6-4 Energy and Utility

In Mongolia, particularly in Erdenet city, there is a big handicap compared with other smelters as a location of smelter from the point of energy (power and fuel) availability, utility (industrial water, flux, etc.) availability and market location.

### 6-5 Utilization of Sulfuric Acid (Phosphoric Acid Fertilizer Production)

The treatment of sulfuric acid gives greatest technological and economical impact to the project. The followings may be considered to solve this issue.

(1) Recovery as elemental sulfur and not as $H_2SO_4$

This process is to recover elemental sulfur by hydro-metallurgical process (high temperature, high pressure treatment by an autoclave) and at the same time, obtain $CuSO_4$ solution from which copper cathodes are produced by electrolytic recovery. This process has not yet been commercially proven and further, the recovered elemental sulfur contains a small quantity of heavy metals which makes it less competitive in the market when compared with the sulfur

recovered by desulfurization of heavy oil. There are two zinc smelters in Canada where about 20,000 tons/year of elemental sulfur is recovered but they also have difficulty in its sales. It has been reported that they are piling up the recovered sulfur in the plant.

(2) Production of fertilizer from sulfuric acid and phosphorous ore

For the treatment of sulfuric acid, it is good to convert it to phosphoric fertilizer. In this case, a demand in surrounding countries can be expected and it is not so difficult from technical point of view and is excellent from economical point. However, the fact that the expected phosphorous mine is located in the national park makes the development difficult. It is preferred to develop phosphor mine around Hubusgul Lake without destroying the environment, particularly the ecological system.

It is expected to continue a research challenging the "Continuous development" focusing first on the environmental preservation.

## 6-6 Treatment of Arsenic Contained in Copper Concentrate

The copper concentrate from Erdenet Mine contains 0.3 to 0.40% arsenic (As).

The standards for purchase of concentrate by custom smelters is generally As $<$ 0.1% and more than the As penalty payment, it becomes a big problem for the sales of concentrate itself.

In smelter and refinery, a special technology and facilities to remove arsenic are required to prevent this As to create no disturbance to the operation as well as to prevent contamination into the final product copper cathode.

There is a special concentrate from a certain mine containing Cu$>$ 30%,

Au : 50 g/t, Ag : 200 g/t but As > 10% and in this case, a pretreatment to remove As by a fluidized bed roasting (650°C) is done.

However, the residual As in the calcine from this case is about 0.3% which is almost the same as concentrate from Erdenet Mine.

If the concentrate is of high As content as in this case, a complicated As removal process may be introduced and the pretreatment cost may be recovered by high gold and silver contents but the concentrate of Erdenet Mine which is about 0.3% As content is not high enough for pretreatment and makes the situation difficult.

For the construction of copper smelter, it is better to equip a sufficient As removal technology and facility.

## 6-7 Study on Hydrometallurgical Processes

During the discussion with the metallurgists in Mongolia, their strong interest in gathering information on hydrometallurgical process was noted.

This is because of its attractiveness on not recovering sulfuric acid but consuming it, also that the process meets a small 10,000 tons/year capacity of the plant and that it meets the capacity of copper fabrication.

Of course, there are disadvantages coming from its small scale but it is worth studying and therefore, technical documents available in Japan were furnished to related metallurgists.

The hydrometallurgical processes now under study for introduction are as follows.

(1) The Cuprex Metal Extraction Process

(2) Nitric-Sulfuric Leach Process

(3) Sherritt Gordon (COMINCO) Process

(4) Cymet Copper Reduction Process

(5) Arbiter process (ANACONDA)

(6) Bacteria Leaching & SX-EW Process

According to information we have, Erdenet Mine has already tested on a pilot plant scale for low copper content tailing treatment by the Morrison-Knudoson's, USA and we recommend to further investigate the details referring to this result.

## 7. Economic and Financial Recommendations

### 7-1 Detailed Feasibility Study for Construction of Copper Smelter

The "Report" analyzes the economy of the project based on investment recovery period method for each plant.

It evaluates the economy focusing on the expected profit per year from each plant after start of operation and the number of years required to recover the investment.

The period of recovery of plant investment is calculated as follows.

(1) 100,000 t/y copper smelter and refinery 7 years

(2) Pyrite concentrate treatment plant 22 year

(3) Phosphoric acid fertilizer plant 14 year

After the elapse of this recovery period, the profit obtained from the plant is all enjoyed by the investors and therefore, it is better to have as short recovery period as possible.

It differs from case to case but generally speaking, a guideline would be recovery in 10 years.

Therefore, in this case, pyrite concentrate treatment plant and phosphoric acid fertilizer plant may be judged to have too long recovery period.

Since the program itself is in very premature stage at the moment, it is unavoidable to have this simple economical analysis only. However, to promote the project more specifically, it is necessary to have more detailed feasibility study which required quite a large amount of money and time.

It is recommended to request the overseas consulting firm for the

preparation of a feasibility study which could be accepted internationally (to be the basis of evaluation by overseas investors).

### 7-1-1 Evaluation Method

Generally speaking, there are several methods for the economical evaluation of the investment. The investment recovery period method used in the "Report" is one of the established method.

However, this method is said to have disadvantage of not clearly calculating the profit after recovery of investment as a return to the investment.

If a foreign fund is considered as one of the financing sources, a rational economical analysis to meet the investment evaluation standard of foreign investors should be adopted.

Foreign investors would request recovery of investment in a shortest possible period and a stable profit.

We recommend an evaluation by a method to evaluate "profitability" and which is used internationally among the investors which is the Internal Rate of Return method (so called IRR Method). At the same time, in order to evaluate the impact to the national economy, EIRR method evaluation should also be done.

### 7-1-2 Overall Evaluation of the Entire Project

The Report analyzes the economy for each plant but this should be considered in overall plant.

The copper smelter construction project should be organically combined with its up stream and down stream. The copper smelter functions only when plant, energy, transportation, water and other related infrastructures are well

maintained. Any deviation in the surrounding infrastructure program will cause failure of the project.

Therefore, the financing program and study on economy should be done taking into account the entire related facilities.

In other words, the profitability of the project and its influence to the national economy should be justified not by the partial evaluation of the investment and profitability but from the overall point of view utilizing IRR and EIRR methods calculation.

## 7-2 Justification of Construction Cost

The construction cost of 450 million US$ reported in the "Report" will be more than 20% higher with the cost estimation done now. The reasons are enumerated hereunder.

(1) The site construction cost is omitted which should be added.

(2) Related infrastructures and utilities are required.

(3) Interest during construction and initial working capital are also required.

Taking an example of a certain copper smelter with the production capacity of 100,000 tons/year, the investment is categorized as follows.

(Plant Cost)

a. Equipment and construction cost

b. Engineering fee

c. VAT (Value Added Tax)

(Owner's Cost)

a. Infrastructure, utility

b. Concentrate, products handling system

c. Licensing fee, technical research and development cost

(Others)

a. Interest during construction

b. Initial working capital

With the above category and on 1990 basis, the total project cost for the above plant is 600 to 700 million US$. Further, the owner should also consider the contingencies taking into account the inflation rate and other unexpected situations.

The construction period of a smelter is related with the situation for preparation of infrastructures and utilities but normally, it takes 3 years for design and construction, and the commissioning starts on the 4th year. A preparation period of 1 to 2 years is required for the establishment of a company, personnel recruiting and training and therefore, it will take minimum 5 years before the first production starts. This is after the approval by the Government and the time required for such approval should also be added.

## 7-3 Financing Source

The basic concept is to introduce fund from foreign sources and considering the fact that domestic financing is not ready, and the investment amount is over one billion US dollars, there is no other way but this foreign financing. The followings can be considered as a financing sources of the project.

(1) Utilizing cash flow from Erdenet Mine

(2) Utilization of foreign government aid

(3) Introduction of foreign private financing

(4) Loan from foreign financing organization

Of the above, items (1) has to be considered from the entire country's economy due to the fact that it is a matter of how to effectively utilize the limited foreign currency.

Case (3) is a practical and realistic financing method but to prepare for it, is necessary to organize a legal structure and privileges for foreign financing. The western capital particularly requires this.

At present, Mongolia is working on the preparation of investment environment but to have active foreign investment, the Mongolian economy has to grow and stabilized. It seems to take time before materialization.

Case (4), loan from foreign country, is one of the possible financing measures but it is impossible to depend the entire cost and this should be considered as one of the measures to finance a part of the project.

A loan from private banks seems to be difficult until the domestic economy is stabilized. A contact with public organization such as World Bank and Asian Development Bank should also be considered.

A loan from western enterprises who are the consumers of copper products will be settled by price deduction at the time of product delivery. If this method becomes possible, there will still be a limitation of the amount, which depends on the total quantity of business transaction. Over transaction will cause shortage of fund required for operation.

When financing is considered, and if the total amount is to be financed from foreign source, financing of a vast amount of one billion dollar seems quite

difficult. From the point of financing, the materialization of this project seems quite difficult.

### 7-4 Organization of New Smelting Company

For the establishment of smelting company, there are two ways, one is to incorporate it as a division of Erdenet Mine and the other is to establish it independent from Erdenet Mine.

The proposed smelter requires concentrate form sources other than Erdenet Mine and if the financing is to be done from all over Mongolia, it is more practical to have it as a company independent from Erdenet Mine. From the point of personnel, engineers and management, the running of the smelter is better to be closely related with the management of Erdenet Mine. At any rate, it is better to be incorporated as one of the Erdenet Complex to have strong relation and the management to run together with Erdenet Mine.

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