THE STUDY ON MODERNIZATION PLAN OF BENEFICIATION PLANTS OF CFM IN THE UNITED MEXICAN STATES

FINAL REPORT

(SUMMARY)

March, 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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SUMMARY

1. Summary of Mining Potential

(1) Parral Beneficiation Plant Area

Ore deposits surrounding Parral beneficiation plant have a long history, but there are a few spots subjected to a large scale mining in the past. Oxidized ore zones have not been exhausted and almost all sulfide ore zones remain intact, resulting in an estimation that there will be a sufficient amount of ore reserve. Ore grades are high and stable. The operation of mines is steady with an expectation of a stable supply of ores for the long term.

(2) Guanacevi Beneficiation Plant Area

This area has been exposed to large scale mining operations for a long time, with oxidized and ore sulfide zones that have been almost completely mined out. Therefore, the main ore supply from this area consists of the remaining minerals and some old waste that can now be mined. Although the mines are well equipped with facilities, the ore reserve is insufficient. The exploitation of the ore supply from the Santa Cruz Mine will expectedly fulfill the beneficiation capacity of this plant for the coming two years, therefore new ore deposits should be discovered with a possible exploration encouragement by cooperation of the CRM.

(3) Barones Beneficiation Plant Area

This area has a long history and is crowded with veins of abundant ore reserves. Because the past mining operations focused mainly on oxidized ore zones, discovery of sulfide ore zone can be expected. Unlike the other two areas, ore grades in this area are generally lower, because of the lower beneficiation fee. Mines are full of spirit, and construction of private beneficiation plants and leaching plants are proposed. Ore production may be maintained for a long term, but the production quantity and ore grade may fluctuate because of the influence from private ore treatment.

2. Summary of Beneficiation Tests

As a result of chemical and physical analyses of ores from 18 surveyed mines, some 70% to 80% of the silver is from sulfide mineral and the rest is native silver.

As to beneficiation tests, the result of investigation on reasons why silver recovery is low from Casare ore in Parral area has revealed that the silver is difficult to recover because it is contained in quartz. Beneficiation tests also have indicated that the silver recovery from Rosario ore in Guanacevi area can be improved by mixed flotation of oxidized and sulfide ores, and that from Calicanto ore in Barones area by the combination of mixed flotation of oxidized and sulfide ores in conjuction with cyanidation.

3. Summary of Diagnosis on Status Quo of Beneficiation Plants

Diagnostic results and proposals for improvements are commonly applicable to the three beneficiation plants. Among these proposals, improvements in the beneficiation recovery, in the production rates of facilities and in the maintenance of equipment, and measures to cut down the operating cost are mutually related. The basic items for them are instrumentation and automation for the beneficiation plant, establishment of the maintenance and repair systems, and conversion of the Maquila System into the All Ore-Purchasing system.

First of all, the instrumentation and automation is aimed to improve experience with the process, eliminate too many hands, extra unneeded materials, waste of energy, and their influences on the cost, recovery and production rate, resulting in a steady operation. To realize this target, many factors such as ore supply, grinding grain size, water supply, extra quantities of reagents, pulp concentration and pH value must be controlled, and data must be compiled from the daily operation to comprehend the optimum conditions for these factors. Instrumentation provides objective data on a continuing basis. In addition to these hardware elements, it is also important that operators and staff acquire skills for operation and management.

Secondly, the disruptive state in which a machine breakdown is repaired presently interfers with the normal process, makes for inadequate operational load factors, and reductions in the overall operation efficiency, while increasing maintenance cost, and causing an unsuitable lack of parts and spares, with a resultant decrease in the production rate of the facilities. Therefore, here we proposed to establish a preventive maintenance-repair system as an integrated means to cope with these problems. To be specific, routine inspection for maintenance purposes should begin immediately - some operators should examine the facilities by using check-sheets. Then annual plans for maintenance and periodical suspension of operation for maintenance should be incorporated, and inspection results should be recorded in the maintenance log for each piece of equipment such as data for planned maintenance and proper inventory of spare parts of developed for the future. In addition to these measures, failure detector devices should be introduced to reduce the load of workers and to avoid erroneous oversights.

The mixed beneficiation system of Mquila and Ore-Purchasing has many faults, such as time loss due to the intermittent operation, the beginning of operation, during the suspension of operation and the production waiting time; waste due to overuse materials; changes in the operational conditions by ores; the complexity of the process; and resultant decrease in the productivity rate. The only way to solve the problem is by switching the system to the All Ore-Purchasing system to solve these problems. This conversion will not only improve on these faults, but also will enable the establishment of monthly and annual maintenance and budget plans and the introduction of a controlled beneficiation system. To realize this conversion, the conditions for purchase recovery should be more equitably defined by test results of beneficiation recoveries in the past and recoveries obtained from beneficiation tests. The conditions for purchase recovery will be revised step by step by accumulating monthly data. The lower limit of ore grade should be determined for purchasing arrangements. Specific purchasing conditions should be decided for ores that are difficult to treat. The ore purchase system should be finalized by adding these conditions to the beneficiation conditions, T/C, R/C, penalties and the sale cost. There may seemingly be a variety of ore types that come from respective mines, but they stem from a group of ore deposits when viewed from a

geological standpoint, and therefore it may be sufficient to classify these ores into five types - oxidized ore, sulfide ore, high grade ore, low grade ore and difficult to treat ore.

An planned management system is proposed to improve the administration division. The system is run by tallying the actual practices within the plant to the budget prepared on the basis of sufficient consideration to identify any abnormal values, and to investigate its causes and remedies, and to plan for the future and to establish measures which correspond with that prospect. This data is compiled and fedback to operations, and then is parlayed into the profit analysis and the optimal personnel plan. With such a system, an integrated income/outgo budget can be prepared based on projected costs for raw material management, ore treatment planning, ore acceptance, analyses and administration on the premise of annual or semi-annual budgets. Also needed is a personnel plan and a finance plan. These budgets and plans are compared to the monthly reports. To simplify the work, save labor and to provide an appropriate personnel dispostion for the work, personal computers should be introduced to record data on various books and to analyze results, providing a basis for sound operation and management.

4. Summary of Current Economic Analyses

CFM has raised the beneficiation fee charged since January, 1989, and the beneficiation fee per ton is now at 30,000 pesos (13 US$ for custom ore). At the Barones beneficiation plant, however, the fee rise is insufficient to resolve the beneficiation fee at 16,500 pesos (17,500 pesos for purchased ore) because of the protest of the association of medium and smaller miners. As a result, the first half of fiscal 1989, the records indicate the costs on a per ton of treated ore basis are profiting by 5,228 pesos for the Parral plant while a recurring loss of 3,815 pesos continues at the Guanacevi plant, and a staggering recurring loss of 15,799 pesos for the Barones plant. If the beneficiation fee of 30,000 pesos were applied to the Barones plant, the record would be a recurring loss of only 1,990 pesos.

Accordingly, major themes for modernization plans for beneficiation plants are for raising the efficiency of the Parral plant, reducing the loss and raising the efficiency for the Guanacevi plant, and reducing losses as much as possible.

(1) Parral Beneficiation Plant

The plant is held under sound operation without any big problems except that the assets have not been reevaluated. The break-even point indicates that the plant would not go into the red even if the sales were to go down to around 2/3 of the current value - the operation is extremely sound and stable even as it is.

It is feared, however, that these facilities have become obsolete and worn down because there have been no investments for the long term to maintain and renew the equipment. It is important that a revaluation of the assets show proper depreciation values so that investment for maintenance and renewal of facilities is possible.

(2) Guanacevi Beneficiation Plant

The plant has shown a large deficit for almost every year. It is difficult to expect a big increase in the sales because of a downward trend of the ore treatment quantity in future due to the low mining potential of this area.

To improve the income and outgo, there is no way other than to cut down, considerably, the prime cost through better organization of the operation. For instance, the income and outgo can only be balanced when a third of the personnel expenses, 15% of the power expense and the material cost are reduced. These cost reductions must be realized through strict operational control because the current personnel organization and operational cost are fairly loose.

(3) Barones Beneficiation Plant

The plant is compelled to show a very big deficit each year, with the largest problem among any of the three plants surveyed. The cause for the loss is that the contracted beneficiation fee and the purchased ore beneficiation fee have been suppressed at a level much less than actual beneficiation cost.

To dissolve the red ink, the cost of operation must be substantially cut, and at the same time the beneficiation cost must be increased to an equitable level. The revision of the beneficiation cost has already become a political issue, so that it may be difficult to request a raise in the beneficiation cost to an appropriate level similar to that of the other two beneficiation plants. Accordingly, the improvement of the present conditions can only be achieved if a new beneficiation plant equipped with modern facilities would additionally be built by using funds to raise the current low recovery rates, and the operational costs reduced by resolutely executing modernization controls, while at the same time raising the beneficiation fee even by the minimum.

5. Summary of Modernization Plans for Beneficiation Plants

(1) Modernization of Existing Facilities in Parral Plant

The modernization plan aims at measures against obsolescence of, maintenance of, and efficiency improvement of facilities; stabilization of operation; improvement of labor conditions; and achievement of labor-saving. Current conditions are: ore treating quantity = 6,400 t/month, Au = 0.74 g/t, Ag = 325 g/t, Pb = 0.2% and Zn = 0.2%. A modernization can raise those beneficiation recovery rates for each metal by 2% - 3%, so that new rates recoveries are Au = 67.02%, Ag = 68.25%, Pb = 52.5% and Zn = 47.25%.

The details of the modernization work are:

(a) Replacement of worn out ball mills
(b) Reinforcement of dust collectors as a measure against the dust in the crushing system that causes troubles in machines and electric filter systems, and pneumoconiosis in laborers
(c) Instrumentation to stabilize the operation
(d) Organization of the administration division to save labor and to manage the business faster and more correctly.

The capital spending would be 1,493 million pesos (563,000 US$), and the production cost will be reduced by 3,556 pesos per ton of treated ore. This value plus the current recurring profit of 5,288 pesos will contribute to the promotion of mining in this area.

For reference, the IRR is 19.9% - 18.0% when the market price of silver falls by about 10% and 21.7% when the price rises by some 10%, and the ARR (Accounting Rate of Return) is 18.3% and the PB (Payback Period) is 5.5 years.

Conditions concerning the investment are:

(a) The market price of each metal used as the base for the income calculation is the average of international market prices of the metal during the period from January to June, 1989.
(b) The smelting conditions for concentrate selling are those of IMMSA (a major smelting company in Mexico).
(c) The interest is assumed to be 5% because of a promise of loans from international financial institutions like the Inter American Development Bank (IDB).
(d) The term for depreciation is 10 years for machine and equipment, 15 years for buildings and structures, with a scrap value of 5% and the fixed installment amortization.
(e) The exchange rate between the peso and the US dollar is 1 dollar = 2,650 pesos, which was the rate at the time of this survey.
(f) The total amount of improvement is the sum of the increase in income corresponding to the investment (the increase in beneficiation recovery rates) and the reduction in the cost corresponding to the investment (the decrease in beneficiation cost and general

administrative cost), and the IRR is calculated on the basis of the total amount of improvement through the DCF method.

(g) The investment efficiency, the ARR (%), equals to [total amount of improvement - (depreciation expense + interest)] / investment amount.

(h) The recovery term, the PB, is the number of years to recover the investment, and is shown as 1/ARR.

(i) Many factors such as the beneficiation recovery and the ore grade can be used for the sensitivity analysis, but the market price fluctuation of silver is adopted in this case. The fluctuation range is around 10% in the upper and lower sides of the average shown in (a).

These conditions have also been applied to the other two beneficiation plants.

(2) Modernization of Existing Facilities in Guanacevi Plant

Purposes of the modernization are for maintenance of facilities, energy-saving, stabilization of the operation, reduction in commodity expenses, and labor-saving and organization of the administration division. Prior conditions are: ore treating quantity = 7,751 t/month (the present amount). Au = 1.45 g/t and Ag = 253 g/t. The modernization can raise the beneficiation recovery for Au and Ag by some 2.3%, so that the expected recovery is about 80% for Au and Ag.

The details of the modernization work are:

(a) Installation of filter presses for energy-saving

(b) Improvement of the grinding system for energy-saving and stabilization of the operation

(c) Reinforcement of reagent facilities necessary to cut down on reagent cost and to stabilize the operation

(d) Reorganization of the floatation system for energy-saving

(e) Organization of the administration division for labor-saving.

The capital spending for the modernization is 810 million pesos (306,000 US$), and the production cost will be decreased by 5,155 pesos per ton of treated ore. This reduction brings about a recurring profit of 1,340 pesos/t rather than continuing the current deficit, without causing any additional burden to the mines.

For reference, the IRR is 49.5% - 47.5% when the market price of silver falls by about 10% and 51.5% when it rises by some 10%, and the ARR is 59.2% and the PB is 1.7 years.

(3) Barones Plant

The working rate of the plant is so low that the mines restrict their ore production or stock their ores at their own mining sites. Ores of high grade and mass-production are treated in the CFM's near El Bote Mine at a high beneficiation fee. Furthermore, medium sized mines provided with large ore reserves are planning to build their own beneficiation or leaching plants, and private contract or purchased beneficiation plants are being built to deal with ores from medium and smaller mines. These conditions and the cheap beneficiation cost of the plant has caused a trend that ores of only low grades, where treatment is difficult and small lots are supplied to the Barones plant, while ores of good quality, high grade and large lots flow out to other beneficiation plants. This has resulted in repetition of a vicious cycle of reductions in recovery and production rates, and resulted in red-ink operations. Improving the status quo of the plant will be extremely difficult, and the only way is by the combination of improvement of existing facilities with the installation of a new beneficiation factory aiming at raising the recovery rates and the added value of sulfide ores.

(A) Modernization of Existing Facilities

Prior conditions are: ore treating quantity = 9,056 t/month (the present amount), Au = 0.47 g/t and Ag = 175 g/t. Then proposals are:

(a) The result of beneficiation tests has revealed that a mixed treatment of oxidized and sulfide ore could improve the recovery rate. Therefore improvement of the flotation and the cyanidation systems to realize a mixed treatment.

(b) Instrumentation and automation to stabilize the operation, to cut down the cost of purchased goods and to improve the labor conditions (especially mechanization of the monitoring system)

(c) Improvement for labor-saving and organization of the administration division

Capital spending is expected at 612 million pesos (211,000 US$), and the operation cost will be reduced by 4,262 pesos per ton of treated ore. Expected rise in recovery rates should be 2% for Au and 4% for Ag, and 21 workers can be eliminated.

For reference, the IRR is 52.1% - 51.0% when the market price of silver falls by about 10% and 54.4% when it rises by around 10%, and the ARR is 63.7% and the PB is 1.6 years.

(B) Construction of New Modern Beneficiation Plant

Adjacent to the existing plant, a new beneficiation plant (crushing - grinding - floatation - dewatering) will be built for a differential floatation method of Pb-Cu-Zn recovery. The planned ore treatment quantity was investigated for two cases - 150 t/day and 200 t/day, because the proper quantity was assumed to lie between the two amounts when the ore stocks and production restrictions of mines were taken into consideration. The expected ore grade is: Au = 0.8 g/t, Ag = 160 g/t, Pb = 0.8%, Cu = 0.4% and Zn = 1.6%, and the expected beneficiation recovery rate is: Au = 33%, Ag = 76%, Pb = 73%, Cu = 86% and Zn = 68%. The labor force contains 21 workers.

The equipment includes:

(a) Machines and electric facilities

(b) Civil engineering and construction work.

The total investment amount is 16,025 million pesos (6,047,000 US$) for the 150 t/day capacity, or 17,628 million pesos (6,651,000 US$) for the 200 t/day capacity. The resultant reduction in production cost will be 2,762 pesos (@150 t/day) or 11,006 pesos per ton (@200 t/day) of treated ore, and therefore the total modernization effect including the advantage derived from the modernization of existing facilities will become 8,451 pesos or 12,487 pesos. As a result, the current deficit of 15,799 pesos will be reduced to 7,348 pesos or 3,312 pesos but is still in red. This remaining red can only be borne by medium and smaller mines as part of a revised beneficiation fee.

The conclusion is to implement the modernization plan and to raise the beneficiation fee from current 16,500 pesos/t to 25,000 pesos/t.

For reference, the IRR related to the new beneficiation plant is 6.5% for 150 t/day or 9.2% for 200 t/day, which, when added to that for the modernization of existing facilities, becomes 8.5% for the former or 10.7% for the latter. The construction terms of the new plant is two years.

1. INTRODUCTION

According to the policies for economic reconstruction of the Mexican government, Comision de Fomento Minero (CFM) of Republic of Mexico Ministry of Energy and Mining (SEMIP) is now executing measures to rationalize and to raise the productivity of the national enterprise.

This report describes results of the survey on the policies of the modernization plans for the three beneficiation plants which the CFM is managing. The survey, as a part of the above-mentioned measures, was conducted on the basis of the Scope of Work, on which the CFM and the Japan International Cooperation Agency have agreed and signed in September, 1988.

Medium and smaller private mines distributed in the United Mexican States are so frail in economic foundation and technical capability that they cannot afford their own beneficiation plants. Therefore the CFM has built and is managing a beneficiation plant in each mining area, and medium and smaller mines over one thousand are enjoying the benefits from these beneficiation plants. Many of the CFM's beneficiation plants, however, are forced to operate with deficit because of low beneficiation recoveries and facility production rates, which has resulted in application of the above-mentioned measures for reorganization and productivity improvement.

The following beneficiation plants were selected as the subjects of the survey.

(1) Parral beneficiation plant in Chihuahua State
(2) Guanacevi beneficiation plant in Durango State
(3) Barones beneficiation plant in Zacatecas State

In addition, six mines related to each of the three beneficiation plants were investigated.

Purposes of the survey of the three beneficiation plants are as follows.

(1) Reduction of the operational cost
(2) Improvement of the facility production rate
(3) Improvement of the beneficiation recovery rate
(4) Investigation and evaluation on expansion, diversification and integration of production processes
(5) Improvement of the facility production rate by establishment of a preventive maintenance system.

Prior to the field survey, a preliminary study was carried out in Japan, based on which survey plans were made and the inception report was prepared. The inception report was submitted and explained to, and discussed with the CFM, and then the field survey began. In the field survey, the following items were carried out.

(1) Gathering and compiling data and materials
(2) Examining mining potentials
(3) Investigating the status quo of beneficiation plants
(4) Beneficiation tests
(5) Collecting financial and economic data
(6) Diagnosing the current conditions of beneficiation plants.

Immediately after the field survey, a summary of the field survey was reported and discussed at the site, and these results were arranged into a progress report, which was then submitted and explained to, and discussed with the CFM.

Results obtained and materials gathered through the field survey were analyzed and tested in Japan with the following items.

(1) Analyzing and compiling results of the field survey
(2) Executing beneficiation tests and analyzing their results in Japan
(3) Evaluating mining potentials
(4) Making conclusions from the diagnosis on beneficiation plants and preparing proposals
(5) Preparing modernization plans for beneficiation plants
(6) Evaluating the economic efficiency

The draft for the final report was drawn up by putting together the above items. The draft was submitted and explained to, and discussed with the CFM, and thus this final report has been completed.

The field survey was conducted by six members of the survey group from Japan and their counterparts from the CFM, with on-the-spot cooperation of the chief and persons-in-charge at each beneficiation plant; the head and persons-in-charge of geology, mining, machinery and electric equipment at the CFM's branch office; the owner and persons-in-charge at each of medium and smaller mines; and an observer from the CFM.

The field survey was conducted on the mining - geological and the economic-financial divisions from July 17 to September 14 in 1989 (60 days), and on the divisions of beneficiation, related facilities and tests, and analysis from July 17 to October 11 in 1989 (87 days). The draft for the final report was discussed for nine days from February 8 to 16 in 1990.

2. BACKGROUND OF THE PROJECT

(1) Current situation of mining industry in Mexico

Mexico is among the most affluent countries in mineral resources in the world.

Mexico has abundant deposits of both metallic minerals such as silver, copper, lead, zinc and other non-metallic minerals such as celestite, fluorite, barite and sulfur.

The mining industry in Mexico has steadily played an important role in promoting regional development, supplying materials for industry, earning foreign currency, and securing employment for her people.

Mining activities are present in about 250 municipalities all over the country and contribute to the direct employment of 221,000 people.

The production of the mining sector reached about 3.8 trillion pesos in 1987 and accounted for 1.3% of the gross national product.
Mexico's output of as many as 14 minerals are listed among the top five of the world of mineral production rankings (excluding communist bloc countries).

Also notable is the export of the mining sector which amounted to about 1.38 trillion pesos in 1987 and accounted for 5.2% of Mexico's total export revenues.

Production shares by type of enterprise in the mineral industry are 54% for national corporations, 30% for large-scale private companies and 16% for middle-to-smaller mines.

With the view of promoting middle-to-smaller-scale mines (about 3,000 all over the country) regarded as one of the three main forces in mineral production in Mexico, the Mexican government has provided technical and financial support for all aspects of mining activities through such governmental agencies as the Bureau of Mining Industry Promotion (CFM), Bureau of Mineral Resource and the Mexico Non-metallic Mineral Fund.

The beneficiation plants on which this study has been conducted was established by CFM around the country as part of the government support program to help minor, middle-to-smaller mines, unable to finance their own beneficiation plants for treating their ore products into refined material. Therefore, they are indispensable institutions for promoting middle-tosmaller mines.

(2) Mexico's policy for its mining industry

1) History

In the colonial era, mining in Mexico was a source of wealth for Spain (the mother country), and in the first century after its independence, Mexico still earned half its foreign currency reserve exporting silver.

In the era of President Porfirio Diaz (1872 - 1911), mining of other minerals than gold and silver and modernization of the mining sector began, state control of natural resources was abandoned, and mining enterprises in Mexico were completely under the control of foreign capitalists and a source of material supply for industrial development of foreign countries.

As the revolutionary government solidified its foundation after the Mexico Revolution, the state control over the mining sector strengthened step by step, resulting in reconstruction of state control. In 1961, the Mining Industry Act was enacted and limited the sponsorship of mine development to the Mexican government, individuals of Mexican nationality, or corporations dominated by Mexican shareholders.

The new Mining Industry Act enacted in 1975 was a result of a re-examination of the strategies and policies with regard to the utilization of natural resources, which became necessary as the national economy grew. The new law strongly required transferees of mining rights to commence development plans without delay and prescribed the direct participation of the government in mineral production activities.

The Mexicanization of the mining industry once controlled by foreign capaitalists, and the reconstruction of a declining mining industry have been pursued by each government subsequent throughout Mexico's history.

However, foreign capitalists have not necessarily been interested in investing in Mexico and development plans did not make progress as they had been expected without sufficient domestic capital.

2) Policy of the present administration for the mining industry

The current Salinas administration has not only advanced the policies of the previous De la Madrid administration, but also moved one step further. It set about a detailed execution rule for the introduction of foreign capital law in May 1989 in which 100% participation of foreign capital was endorsed. As a result, though the maximum share of participation by foreign capital set forth in the new Mining Industry Act (4.9%, but up to 34% in state-owned areas) remained unchanged, if combined with the use of a trust provided by Mexican banks, foreign capitalists would be able to hold the majority of participation share in substance.

Although concrete measures for the mining industry by the Salinas administration are yet to be proposed based on the National Development Plan 1989 - 94, prospective contents are expected to succeed those stated in the "Policy Outline 1988 - 94 (mining industry)", or the proceedings of the Mining Industry Conference held during his campaign for presidential election. In the measures, candidate Salinas made several policy proposals and would expect middle-to-smaller mines to play an important role.

3. SUMMARY AND ANALYSIS OF FIELD SURVEY RESULTS

3.1 Outline of Geology and Ore Deposits

(1) Parral Area

The basement of this area is sedimentary rocks of the Cretaceous age, and is overlain unconformably by sedimentary and volcanic rocks of Tertiary, and dikes intrude in the NNW-SSE direction. In the southwest part of Parral City, there is a large fault in NW-SE direction.

The ore deposits are of vein type and are hosted the Tertiary rocks. The alterations related to the ore formation are of propylitization, silicification and argillization, and igneous rocks related to ore deposition is regarded as Tertiary rhyolite.

Veins operated by the middle-to-smaller mines are distributed in a 12 km x 7 km range north of the Parral City. In addition, subgroups of veins are distributed 19 kilometers south, 30 kilometers southeast, and 40 kilometers north-northeast of Parral City. The direction of the main subgroups of veins are from N-S to NNW-SSE, and concordant with some of the dikes.

The distribution density of veins north of Parral City is three veins per square kilometer. The sulfide ore zone of each vein is oxidized to the depth of 50 m or 100 m below the ground surface.

(2) Guanacevi Area

Basement rocks in this area are sedimentary rocks of Paleozoic, Jurrasic and Cretaceous age, and are unconformably overlaid by Tertiary in wide area. The dikes intrude in the NW-SE direction, and a large fault near the Santa Cruz is observed in the same direction.

The ore deposits in the area are of vein type, with the exception of one manto type. These ore deposits are found in Tertiary volcanic rocks. The alteration related to the ore deposition includes the silicification and chloritization. The veins in the area are distributed in a 10 km x 10 km range and the main direction of vein system

is NNW-SSE, but NNE-SSW is predominant in the western aprt. The distribution density of veins is three or four veins per square kilometer. The depth of the oxidized ore zone is less than 50 m.

(3) Borenes Area

The basement rocks in this area are of Triassic, Jurasic and Cretaceous sedimentary and volcanic rocks. The Tertiary rock unconformably overlies the above basement, and dikes are represented by several northwestern direction plugs which are exposed in the central part of this area. The older fractures in the NWW-SEE direction were filled with vein material, and then cut by faults in the NNW-SSE direction.

The ore deposits are of vein type and were deposited in the basement rocks. It is difficult to distinguish the related alteration to ore mineralization from the regional propylitization. Igenous rock related to ore deposition is regarded as Tertiary rhyolite.

There are five major vein groups distributed in a 50 km x 15 km range, and the veins strike N45° W to N85° W and dip 50° SW-70° SW or 75° NE and are parallel to Tertiary dikes. The depth of the oxidized ore zone is less than some 50 meters below the ground surface. The distribution density of the veins is high and five to six veins per square kilometer.

3.2 Ore Reserve

The ore reserves of the medium and small mines surveyed in this study are discussed in comparison with calculation results based on the vein-related section of JIS.

(1) Outline of JIS's Criteria for Calculation of Ore Reserve

1) The ore reserve is expressed in terms of the natural ore reserve and the minable crude ore reserve.

2) Each of the natural ore reserve and the minable crude ore reserve is classified into three values: the proven, probable, and possible ores.

a) The proven ore is a block surrounded with three or more sides.
b) The probable ore is a block surrounded with two or more sides. The block can be regarded as an probable ore when the reserve and grade of the block can be sufficiently estimated.
c) The possible ore is a block in an area, the presence of which can be geologically predicted but cannot be reckoned as a proven or an probable ore. When borings and the characteristics of the ore deposit from the past allow sufficient prediction on the volume and grade of the area, a block in such an area can also be regarded as an possible ore.

3) Indication of Ore Reserve

The ore reserve is indicated by grades. All grades of the lowest limit and better are classified into certain standard groups, and then the ore reserve for each group is calculated.

When there are two or more ore metals, the major ore metal is regarded as the standard and the quantities of other metals converted by calculated coefficients, are added to the quantity of the major ore metal.

4) Sampling

a) The sampling interval should be 1 (one) m or less for gold/silver ore deposits, and 2 - 5 m for other ore deposits.
b) The sample should be taken by digging a small groove of 3 - 10 cm wide and 1 - 5 cm deep on a line representing the full picture of the ore deposit at a fresh spot. The whole amount of the sample should be analyzed.

5) Specific Gravity

The specific gravity should be decided from measurements on many samples.

(2) Outline of Ore Reserve Calculations on Medium and Smaller Mines in United Mexican States

1) The ore reserve in Mexico is indicated in a mixed form of the natural ore reserve and the minable crude ore reserve specified by JIS.

If the vein width is smaller than the mining width, the latter is used as the vein width. In this case, the calculated ore reserve is the minable crude ore reserve, wherein dilution is not taken into consideration. When the vein width is larger than the mining width, the calculated reserve constitutes the ore reserve.

2) The ore reservation is classified into the proven, probable, and possible ores.

a) The proven ore is a block confirmed with three or more sides.
b) The probable ore is a half of a block confirmed with two or more sides.
c) The possible ore is a quarter of a block confirmed with one side. In addition, when borings allow readily the presence of a block, and mining conditions in the past and the characteristics of the ore deposit sufficiently implicate the volume and grade of the ore deposit, then a quarter of a block in such an area is regard as an possible ore.

3) Indication of Ore Reserve

There is no grade classification of the ore reserve---only the target metal is indicated. There are no converted grade indications based on a standard metal.

4) Sampling

a) The sampling interval should be every one meter for gold/silver ore deposits.

b) The sample should be taken by digging a small groove on a line representing the full picture of the ore deposit at a fresh spot. The whole amount of the sample should be analyzed.

5) Specific Gravity

The specific gravity should be decided from measurements on many samples.

(3) Ore Reserve Calculations of Mexican Medium and Smaller Mines Viewed from JIS's Ore Reserve Calculation

1) Ore Reserve

The case where the vein width is larger than the mining width corresponds to natural ore reserve, but the mining recovery and the percentage of dilution are not taken into consideration. At mining sites, in fact, only the veins are being mined, with very little dilution.

As far the mining recovery, the ore reserve is almost completely mined, resulting in a very high mining recovery.

A vein width smaller than the mining width causes dilution of the grade. At mining sites, however, narrow veins other than veins of high grades are left without mining, bringing about the trend of a lesser mined ore quantity rather than a lowered grade.

2) Certainty of Ore Reserve

The proven ore is similar to that of JIS. The probable ore is a half of that of JIS, and the possible ore is a quarter of that of JIS. Because these reserve calculations are made a part of the basic criteria for the financial studies from CFM, the higher the risk, a larger allowance is considered in the calculation.

3) Indication of Ore Reserve

This is similar to JIS's system of indicating only the metal of the target. There are no grade classifications and no converted grade indications of main metal standard, but the mine owner holds sufficient knowledge on the value of each part of the vein enabling the owner to decide the best course of action relative to the economic conditions.

4) Sampling

Sampling is similar to that of JIS, but the sampling interval is less frequent.

5) Specific Gravity

The specific gravity is decided in a way similar to that of JIS.

From the above description, the trend of the ore reserve calculation on Mexican medium and smaller mines, when compared with that specified in JIS, can be identified as follows.

a) While the ore reserve is somewhat strongly characteristized with the minable crude ore reserve of JIS, the proven ore should be slightly reduced for mining work, and the probable and the possible ores be somewhat increased. The Mexican ore reserve have a secure value with some margin for error, a calculation result less than that obtained using JIS's base.

b) As to the grade, the sampling interval is less frequent than that of JIS, which may result in less accuracy.

3.3 Outline and Mining Costs of the Mines

The outline and mining costs of the mines are shown collectively in Tables 3.1 (a), (b) and (c).

3.4 Outlines of Beneficiation Plants

(1) Parral Beneficiation Plant

Parral Beneficiation Plant is located in Parral City in the southernmost part of Chihuahua State. The distance between the state capital, Chihuahua City and Parral City takes three hours by car.

Between Mexico City and Chihuahua City, it takes one hour and forty minutes by air.

History

1967: The operation commenced under the management by a cooperative association.

Since 1983: As the CFM-owned beneficiation plant, it has commenced the beneficiation of purchased ore of up a capacity of 400 tons/day in the flotation process and 240 ton/day in the cyaniding process. Two flotation systems for bulk flotation and Pb-Zn flotation are used, and the system is varied depending on the ore to be processed.

(2) Guanacevi Beneficiation Plant

Guanacevi Beneficiation Plant is located in Guanacevi, a mining town in the northwesternmost part of Durango State. The distance between the State Capital, Durango City and Guanacevi Town takes about six hours by car.

History

1969: The operation was commenced with a capacity of 100 tons/day. At present, the plant has the capacity of 600 tons/day.

The cyaniding equipment is left outdoors as it has only been about 70% completed because of the suspension of its plan, and the flotation process alone is in operation. The plant is operating entirely in a beneficiation consignment system.

(3) Barones Beneficiation Plant

Barones Beneficiation Plant is located in the suburbs about 2 km distant northwestward from Zacatecas City, the capital of Zacatecas State. The distance between Mexico City and Zacatecas City takes almost one hour by air.

History

1951: The operation was commenced under private management

1961: The Mexican Ministry of Finance participated in the management.

1983: The plant formally became the CFM's place of business.

At present, the plant has the capacity of 300 tons/day in the flotation process and 120 tons/day in the cyaniding process. Sulfide ore is received in a consignment system and oxide ore in a purchasing system, and the former is treated by the flotation process and the latter in the cyaniding process.

3.5 Methods and Conditions of Beneficiation

(1) Parral Beneficiation Plant

In the case of the bulk flotation, the tailing of scavenger flotation is forwarded to the cyaniding process for its treatment.

For the flotation tailings, sodium cyanide (0.3kg/t) and calcium hydroxide (7 to 9 kg/t) are put into the first agitating tank, and agitation and leaching are carried out at pH12, the leached pulp is washed for almost 26 hours by the countercurrent method, and then, gold and silver are precipitated by substitution with zinc dust. The products contain gold by 0.2%, and silver by 70%.

The volume of tailings disposal discharged from the beneficiation plant are approximately 6,000 ton/month and the tailings disposal have been accumulated at the dam. No waste water treatment is carried out.

The total consumption of water amounts to 2.0 m3/t (crude ore), of which about 55% is covered by recycled water in the plant.

The power consumption per ton of crude ore is 65.0 kwh (87.4 to 88.3 on the average).

(2) Guanacevi Beneficiation Plant

The plant is obtaining only bulk concentrates from the bulk rougher, bulk cleaner and scavenger flotation.

Obtained concentrates are dewatered through disc filters, and then are dried using a rotary dryer.

The volume of tailings disposal discharged from the beneficiation plant are about 6,000 ton/month and have been accumulating at the dam. No waste water treatment is particularly carried out.

The consumption of water is 4.3 m3/t(crude ore), of which about 50% is covered by recycled water in the plant system.

The power consumption per ton of crude ore is 45.0 Kwh.

In the flotation, three flotation circuit - bulk flotation, Pb-Zn flotation and Pb-Cu-Zn flotation - are used depending on the composition of crude ore.

In the cyaniding process, the oxide ore is leached at around pH12 with NaCN and calcium hydroxide (8 to 14 kg/t) added, the leached pulp is washed by the counter-current method, and gold and silver are precipitated by substitution with zinc dust. Products contain water by about 30%, gold by 0.15%, and silver by 50 to 80%.

3.6 Beneficiation Results

In the case of Parral Beneficiation Plant, the recovery of gold (Au) and silver (Ag) in each flotation circuit is about 50 to 65%. In the case of Pb-Zn flotation, the recovery of Ag has been improved though the crude ore is lower grade.

In the case of Guanacevi Beneficiation Plant, the total recoveries of both Au and Ag show satisfactory levels of 77 to 78% though they vary depending on the crude ore.

At Barones Beneficiation Plant, sulfide ore is treated in the flotation process, but the effect of mixed oxide ore is deletable in the light of comparison with other plants and on-site conditions. Therefore, the plant should be required to establish the process of the mixed treatment.

3.7 Maintenance Conditions

Each plant has many defects concerning the maintenance of equipment. Actual conditions are that the equipment is repaired only at the time it breaks down.

In order to find a way out of the current condition in which the trouble due to the breakdown of equipment considerably reduces the stability and efficiency of the beneficiation process itself, the preparation of a preventive maintenance plan should be required at the earliest possible time and the establishment of that system for the equipment.

3.8 Equipment Operation Rate

The problem common to the three beneficiation plants is the fact that the ratio of shutdown due to sudden breakdown is very high. The shutdown due to the repair of equipment constitutes a cause that checks the improvement of the equipment operation rate.

Since each plant treats, in a consignment or purchasing system, the ore produced at many surrounding mines, the inevitable idling occurs and the time is lost between processes during the switchover of ore types. However, this constitutes an important factor that brings about temporary ore shortage and lowers the overall operation rate of equipment. At the same time, the factor is also considered as one of the causes that increase recovery loss of valuable metal.

The problems concerning equipment maintenance and ore shortage attributable to the operational fluidity have left adequate room for improvement, and it has been judged that in order to raise the operational rate of equipment, considerable improvement can be achieved by tackling both of these problems.

3.9 Analysis Work

(1) Parral Beneficiation Plant

The analysis work at Parral Beneficiation Plant consists of sampling, pretreatment, wet analysis and dry analysis.

Au and Ag are analyzed by the dry method, and Pb, Zn, Fe and (Cu) by the atomic absorption method.

Although all devices are arranged satsifactorily in the analysis department, many of them are out of order.

The atomic absorption analyzer sometimes become unstable, so that it requires maintenance.

(2) Guanacevi Beneficiation Plant

The analysis work at Guanacevi Beneficiation Plant consists of the sampling at the stockyard, extraction of operation samples and dry analysis. Au and Ag are analyzed by the dry method, and no wet method is carried out.

Although the operation of equipment is almost satisfactory, the installation of an atomic absorption analyzer is desirable for the analysis of Pb and Zn.

(3) Barones Beneficiation Plant

At Barones Beneficiation Plant, ore sampling and analysis are carried out by completely separate departments, and the sampling department performs the weighing of received ore, sampling at the stockyard, extraction of plant operation samples, and pretreatment. The analysis department analyzes Au and Ag by the dry method. The analysis of Cu, Pb, Zn and Fe had been carried out by the titration method, but an atomic absorption analyzer was installed in September, 1989.

Therefore, this analyzer contributes remarkably to speedup of analysis work, but more practice is necessary for improving accuracy.

As the problem common to the three beneficiation plants, it is desirable to hold lecture classes for the improvement of analyzing techniques focusing on the methodology of the Tecamachalco Research Institute.

3.10 Maquila and Ore-Purchasing System

Controversial points concerning current conditions are shown below.

(1) Since ore needs to be treated separately by mine, the shutdown-based loss of time is produced at the time when the ore is switched.

(2) To prevent the ore from mixing together, the remaining-ore removal operation becomes necessary, and constitutes a cause that increases use of operating personnel. In addition, the working environment is bad because of dust.

(3) Separate dewatering of concentrates by mine

In the case of consignment treatment, the necessity of dewatering concentrates separately by mine, causes an increase in workload. The loss of concentrates also amounts to a large quantity.

(4) Short term operation for the same ore makes it impossible to continue stable conditions of operation, so that it is difficult to operate under the optimum conditions.

(5) The necessity of analyzing ore and products (concentrates) separately by mine increase the numbers of sampling and analyses, and causes high production costs.

(6) It is considerably difficult to establish a beneficiation recovery of purchased ore through beneficiation tests for a small quantity of samples.

(7) In regard to the method in which a recovery is determined by calculating balance on the basis of results obtained from the analysis conducted on the spot of actual operation, ore retention in equipment comes into question. Accordingly, such a recovery is not always accurate as that for each mine.

(8) For the ore received from a small mines whose tonnage is dozens to several-hundred tons, in order to comply with separate treatment by mine, it takes a long time in deciding the ore price to be paid.

(9) Each beneficiation plant receives ore from many medium and small mines and must calculate ore prices in accordance with the separate condition of each mine. Therefore, each plant cannot help having a very complicated accounting system of office management.

(10) In the case of consignment operation, the outcome of recovery has no direct connection with the income and expenditure of the beneficiation plant. This seems to be one of causes that restrain the beneficiation operator's desire to improve the job.

3.11 Income and Expenditure

(1) As basic problems common to all three beneficiation plants, the following points can be cited:

1) The equipment has become very superannuated This has caused the decline of operation rate and recovery of the beneficiation plants.

2) The ore is all controlled and beneficiated by lot (mine).
This seems to increase costs and to worsen the operation rate of beneficiation.

3) Each plant has a considerably large number of employees, and a substantial personnel reduction is considered possible.

4) No reevaluation of assets has been performed. Machines and equipment have been depreciated but they are considerably different from current prices.

5) Each plant seems to completely lack the spirit of profit pursuance or any sense of cost control. No budget control has also been carried out.

(2) The following are comments on the investigations on current conditions of beneficiation plants and of our impressions after the investigations.

1) Parral Beneficiation Plant (capacity: floatation 400 tons/day, cyanidation 240 tons/day, and employees 79 persons).

The plant is being operated at surplus and has comparatively few problems under the ore-purchasing system alone. However, the following points should be examined.

a) Considerable cost reduction is considered to be possible by making operational devices. (See the section of beneficiation.)

b) Irrespective of the ore-purchasing system, the ore is beneficiated by lot without exception, so that the control and beneficiation becomes complicated.

c) The plant has received comparatively high grade ore and the recovery is deemed to be satisfactory. The level of operating costs is considerably high as well, but profit is gained because of the large amount (13 dollars/ton) of beneficiation costs, which is to be deducted from ore prices. The plant is located in an area with high mining potential and its stable operation can also be expected in the future.

2) Guanacevi Beneficiation Plant (Capacity: floatation 600 tons/day and employees 96 persons)

The following are problems at this plant:

a) The volume of the consignment beneficiation is decreasing and sales may decline further in the future decreasing in income. It is indispensable to carry out prospecting. (See the section of mining potential.)

b) In spite of performing only floatation, beneficiation costs are very high. The cost of electric power, personnel expenses, consumption of reagents, and expenses for dewatering and drying concentrates might be reduced. (See the section on beneficiation.)

c) In the past, the new installation of cyaniding equipment was planned and about 70% of the entire equipment installation has been completed.

Since then, oxide ore has decreased in volume and the plan for its use has been left discountinued. It is considered that the decrease in output of oxide ore was foreseeable even at the point of time when this plan was started.

3) Barones Beneficiation Plant (capacity: floatation 300 tons/day, Cyanidation 120 tons/day, and employees 122 persons).

Problems of the plant are as follows:

a) In addition to the inferior grade, the ore contains many minerals which are difficult to treat, and its recovery rate is low.

The low level of sales exerts considerable influence on the income and expenditure.

b) The beneficiation cost considerably exceeds the maquila fee (16,500 peso/ton) and ore purchasing fee (17,500 peso/ton), constituting a major cause of the deficit. However, raising of these fees affect the continuation of medium and small mines, and become a serious local problem. Therefore, it is said that unless the recovery rate is improved so as to exceed the figure attained before the equipment of the beneficiation plant becomes obsolete, the cooperation of medium and small mine owners would be difficult to obtain.

c) Major mine owners have been making progress in their plans for constructing beneficiation plants for their own use, and it is forecasted that they will soon discontinue bringing their ore to the Barones Beneficiation Plant. Even if the ore volume can be secured instead from small mine owners with small lots, the decline of grade and diversification of ore types have the possibility of lowering both recovery and operation rates further than at present.

d) In the surrounding area, there are beneficiation plants which perform consignment operations. Each consignment fee is considerably higher than that of Barones Beneficiation Plant, but the recovery rate seems to exceed that of the Plant. It is likely that comparatively high grade ore is brought in the former two plants and low grade ore is sent to the latter.

4. BENEFICIATION TEST

The beneficiation tests, which have the purpose of identific analysis of minerals about 18 mines and for improvement of rate of operation and reduction of operating cost, were carried out. And more, picking up problems of each plants based on the reuslt of investigation of current condition, another tests and investigations were carried out for these.

Summary of beneficiation tests is shown as following tables.

Plant	Sample	Object of test	Content of test	Consideration
Barones	Veta Linda	Improvement of Ag recovery	1. Cynindation tests by addition of $Pb(NO_3)_2$ 2. Cyanidation tests by particle size	Ag recovery was improved by addition of $Pb(NO_3)_2$, and also by more grinding.
		Investigation for effect of elimation of primaly slime on on claryfing in cyanidation process	1. Grinding and sedimentation tests after washing and/or no washing	In spite of elimination of primary slime with washing the secondary slime was producted by grinding and there is no difference sedimentation time between with wash and without wash samples, and so it's difficult to solve this problem by washing of crude ore.
	Don Jesus and another 6 mines	Taking countermesure for dust at crushing plant	Elimination of slime by washing	It's difficult to solve this problem by washing because of primary and secondary slime contain Ag highly.
	Calicanto sulfide, oxide ore	Improvement of the rate of operation and reduction of operating cost	Flotation and cyaniding 1. Sulfide flotation 2. Oxide cyaniding 3. Mixed sample flotation and cyaniding	It's possible to improve Ag recovery by treating of mixed ore, from flotation to cyanidation serially.
	Santa Marta ore	Study of low Zn recovery	EPMA analysis of Zn flotation tailing	No recovered Zn is Zn-oxide (estimated).
	San Bernabe	Estimation of metallurgical result by Pb/Zn differential flotation test	1. Fundamental flotation test 2. Pb/Zn differential flotation test	Metallurgical result was estimated as follows 1. Pb-C Pb Assay 61% Recovery 90% 2. Zn-C Zn Assay 47% Recovery 61% 3. Ag Recovery 57%

Plant	Sample	Object of test	Content of test	Consideration
	18 samples from each mine	Chemical analysis and mineral identification	Complete analysis, X-ray diffraction microscopic analysis and EPMA	1. Main Ag minerals are sulfide (70～80%) and also native silver are observed (20～30%).
Parral	Casale ore	Study on the cause of low recovery of Ag	1. Flotation test and cyanidation test 2. Chemical analysis, microscopic analysis and EPMA	1. No recoveried Ag mineral by flotation and cyanidation is included in Quartz.
	San Luis II ore Noche buena ore La Union	Improvement of rate of operation and reduct-of operating cost	Flotation for individual sample and mixed sample	1. Because of uncorrect results of chemical analysis, could not evaluate.
	Jose Galindo ore	Desliming of crude ore by washing and clary-fing in cyanidation process	Washing and decantation of crude ore	Primary and secondary slimes contain Ag highly. It's difficult to solve this problem by washing.
Guanacevi	Rosario oxide ore	Improvement of Ag recovery	Flotation tests 1. Standard test 2. Increasing of grinding and addition of collector 3. H_2SO_4 and Na_2S addition 4. Decreasing of grinding time	It's able to improve Ag recovery by applying proper operation.
	Rosario oxide and sulfide	Improvement of rate of operation and reduct-ion of operating cost	Flotation 1. Individual sample 2. Mixed sample	Some effect was seen in flotation of mixed sample. They have possibility of improvement of Ag recovery.
	La Prieta ore	Treatment on refractory silver ore which contains manganes	Bacterial leaching test for pretreatment of cyanidation and	1. They have no effect of pretreatment by bacterial leaching on cyanidation and thiourea leaching. 2. Mn was dissolved by bacteria which has sulfur oxidation capacity. 3. Mn extraction rate was high by using thiourea.

5. EVALUATION OF MINING POTENTIAL

5.1 Evaluation of Ore Reserve

The calculation by CFM results in a secure value having a margin for error because it is used as a basic criteria for providing loans and credits such as advance payments for ore and beneficiation. Accordingly, when viewed from the level of JIS, the values of the inferred and the expected ores have to be increased. However, such increases make sense when the mine owner has a will to develop the mine, but they are meaningless when the owner has no ambition to develop the mine.

As a result of examining the ore reserve of each mine by taking these conditions as a premise, no especial problem has been found concerning the ore reserve, except for the partial revision of reserves at La Presa Mine in the Parral area and at San Bernabe Mine and Las Cumbres Mine in the Barones area.

(1) Exploration Potential for Parral Area

Among the six mines surveyed, those blessed with an abundance of ore reserve and stable vein widths and grades are the La Revanncha, La Presa, and Unifocacion Cordero. The veins of the La Esperanza and Tilita are unstable, though there is room for exploration. La Fortuna is not in operation. If these mines are typical for the area, it can be said that the exploration potential of the area is high, because each of the mines is provided with an enough room for exploration.

Future developments can be expected thanks to the remaining oxidized and sulfide ore zones resulting from no large exploitation in the past. The grade of ore is generally high.

(2) Exploration Potential for Guanacevi Area

Superior mines are San Rafael and Ample Al Alto Nuevo Porvenir, being optimistic in both aspects of ore reserve and grade. The other four mines, San Jose Chico, Barraden, Capuzaya, and Noche Buena are operated

by the remaining veins of old large-scale mining and the former low-grade ore. To cope with these conditions, various measures by the government undertaking the pump-up drainage cost and the drilling exploration by CRM can be thought of.

(3) Exploration Potential for Barones Area

Among all the areas, San Roberto, San Bernabe, Calicanto and California mines are blessed with sufficient ore reserves and have room for exploration, so they can be regarded as typical medium-scale mines. While Las Cumbres and Amplicacion San Miguel Miner are small, they hold high grade ores.

In this area, differing from the Guanacevi Area, only the oxidized ore zone has been mined and the sulfied ore zone has been left without mining. This means that there are sufficient room for exploration of the sulfide ore zone. Thanks to low beneficiation fee, low grade ore has been mined, and therefore the basic policy for future operation is to enhance the accessory value of ore by recovery of all components through the flotation.

5.2 Evaluation of Production Capacity of Mine

In practice, by estimating the income and cost balance against the ore grade obtained through the ore reserve calculation, each mine is examined for its possibility to continue a robust and stable operation.

Most mines have not been subjected to exploration yet. If the economic efficiency is high enough, it will allow drift mining at a spot of relatively poor grade ore in a vein, bringing about an expectation of discovering new ore shoots, which means an increase in the ore reserve of the mine, resulting in a long-term maintenance-expansion of the production capacity of the mine.

On the basis of these estimations, the production capacity and the prospects of each area is described in the following.

(1) Parral Area

There is still a margin for error in the funds of each mine. A margin in the funds is especially important for La Esperanza and Tilita Mines where the continuity of the vein is poor, and it is very likely that these mines, can to some extent, cope with raised costs due to mining increasingly deeper parts in the future.

On the other hand, the cash flow level of La Revancha Mine is relatively low because the mine is now operating on oxidized ore containing only silver and the beneficiation recovery rate is low. Accordingly, it is necessary for the mine to shift to the sulfide ore in the deeper part to secure a sufficient amount of ore and to seek ores of higher grade. For this purpose, the change in the current transportation system is required and the increase in mining costs is anticipated, putting the mine in considerably severe conditions.

Despite the risk mentioned above, the production capacity of each mine is judged to be high.

(2) Guanacevi Area

The mines here that are operating at a loss by our calculation will sooner or later be forced to shut down their operations. In addition, the mines now in operation also cannot be expected to have any production increases or a stable output for the long term because of the status quo and room for exploration is limited (San Rafael Mine). Introduction of efficient mining methods is difficult due to the shape of the ore body (Ample Al Alto Nuevo Porvenir Mine). That is to say, reduced output is inevitable if the operation is left to medium and smaller private mining activities.

(3) Barones Area

As a result of our calculations, the income and cost balance is in the black for every mine in this area. However, there is a fortunate aspect in the beneficiation fee, when compared with that of the other two areas, it is suppressed at a low level for some mines.

The potential of ore reserve is high in this area, where a lot of large and small veins, though with somewhat lower grades, lie over a wide range. The latent production capacity of crude ore is high.

5.3 Evaluation of Mining Potential

(1) Parral Area

(a) There are two large vein systems, one north of Parral City and another running from San Francisco del Oro to Santa Barbara, and other small vein systems. The vein system located north of Parral City and other small groups are operated by medium and smaller mines.

(b) In the zone north of Parral City, a small number of the veins have been mined out already, but many others remain intact. Ore has been only slightly subjected to mining. Therefore the general potential of ore production in this area is high.

(c) The vein width and the ore grade are stable for some of the veins, but are not stable for others. Since ore production depends on the stability of a vein, it is considered that operation of unstable veins will have some influence on the ore production.

(d) Medium and smaller mines will hold their current production capacities because of their profitabilities. Steady ore production will be continued because there is no move to increase the ore throughput and no mine will decrease its ore production due to a reduced ore reserve.

(e) Reflecting the dull market prices of gold and silver and the increasing cost for contracted beneficiation, the operation tends to aim at mining ores from the sulfied ore zone, setting aside the the oxidized ore which the recovery rate is low. Accordingly, among the ores to be received by in the Parral beneficiation plant in future, ores from the sulfide zone will increase.

(f) Beneficiation studies are needed for ores with low beneficiation recovery rates like those from La Revancha Mine.

(2) Guanacevi Area

(a) The ore deposit of this district consists of veins crowded into a range of E-W 10 km and N-S 10 km. Some veins are in operation or under exploration by medium and larger enterprises and other are in operation by medium and smaller mines.

(b) Ores have been mined from oxidized and sulfide zones in a large scale down to the deeper part. Therefore the ores that are now being mined are:

(i) Waste from the old mines which are now worthy as ores. These ores are divided to two classes. One is Terrero that is piled on surface, and another is filled in cavities in the underground.

(ii) Low grade ores in old mines that were not worthy for mining then but are now, so-called residual ores.

(iii) New ore deposits recently discovered.

Among the above, (i) and (ii) compose the main types. Their throughput tends to fall under the influence of dull market prices of silver and the high cost for entrusted beneficiation. The remaining ore quantity is also decreasing. Discovery of new ore deposits can be expected, but the ore quantity will not be large because of the limited range of exploration.

(c) Production capacities of medium and smaller mines are sufficient, thanks to introduction of machines to some extent and well desined underground structures, but it will become difficult for many mines to maintain steady ore production because their ore reserves are being depleted. Furthermore, the grade of ore produced is low, and mines operating in the red will sooner or later be forced to close.

(d) The above-mentioned decrease in ore production will be filled with entrusted beneficiation of 5,000 t/month ore supplied from Santa Cruz Mine of Penoles to the Guanacevi beneficiation plant for the coming two years.

(e) During the two-year period, new ore deposits must be discovered with a possible exploration encouragement by cooperation of the CRM. There are some inferred veins in this area, bringing credence for exploration.

(f) In this area, groundwater pressure makes any downward development difficult. To cope with this problem, therefore, it is desirable that CFM consider grants subsidies to encourage medium and smaller mines.

(3) Barones Area

(a) The ore deposit is distributed in a wide range of 50 km x 15 km, extending from the south to the north of Zacatecas City, and it consists of five big vein systems. Among them, part of the Veta Grande vein group has been mined by Penoles Mining Co., Ltd., and part of the Catela vein system is now in operation as El Bote Mine of CFM. All but these two parts are in operation by medium and smaller mines.

(b) The part from the ground surface to the oxidized ore zone has already been mined, and only main galleries have been excavated in the sulfide ore zone. The ores that are now being mined by medium and smaller mines are:

(i) Waste from old mines now worthy of mining -- an ore named Terrero piled on the ground surface.

(ii) Left ores in oxidized zones from old mines and ores existing in sulfide zones.

(iii) Ores in new ore deposits recently discovered.

Among the above, medium and smaller mines are mining the (ii) class, but there are some large ore deposits in (i) and (iii) clases.

Therefore, the ore reserve potential of this area is high.

(c) Medium and smaller mines are provided with a sufficient production capacity, but they stock surplus amounts of ores at their mining sites or surpress production because of the acceptance limit of the Barones beneficiation plant. In contrast, there are some mines that are able to continue operation thanks to the low cost of entrusted beneficiation.

(d) Because of the limited capacity of Barones beneficiation plant, there are plans to build up a private beneficiation plant to treat that areas ore, a beneficiation system that would buy ores from some other medium and smaller mines, and heap leaching of Terrero.

(e) It is necessary to raise production and the recovery rate of the Barones beneficiation plant.

6. MILL PRESENT CONDITION DIAGNOSIS, SUGGESTIONS AND CONCLUSIONS

6.1 Improvement Plan for the Mineral Processing Recovery

(1) Comprehension of the Optimum Conditions by Stable Operation

In order to improve the recovery of mineral processing, it is important to seize the optimum conditions such as "the proper quantity of reagents added" and "the PH value" at that time.

The optimum conditions at an on-site operation does not always conform to what is determined by a mineral processing test at an laboratory. There-fore, to attain a recovery improvement, it is essential to find the optimum operating parameters by controlling the quantity of reagents added while observing the state of flotation froth, analyzed values, etc.

(2) Stabilization of Operation by Means of Instrumentation

The instrumentation has hardly been used in these three plants. Therefore, the operation will never be stable unless important factors, such as the quantity of ore feed, quality of water supply, pulp density, grinding size, PH values, the quantity of reagents added, etc., are constantly monitored and controlled, so that the instrumentation will allow automation to be performed.

(3) Stabilization of Operation due to Improvement of Maquila and Ore-Purchaging System

The present system of Maquila and Ore-Purchasing make the stable and continuous operation impossible because the operation is often interrupted. Therefore, it will be necessary to make the operation continuous and stable by adoption of a new All Ore-Purchasing system , which is described later. In addition, adopting the All Ore-Purchasing system makes the mixed processing of sulfide ore with oxide ore possible, consequently it is practicable to select the best process of each mill for the improvement of recovery.

(4) Master of Operation Control Technique

The improvement of recovery can not be achieved only by installation of modern equipment. It is very important that the operators and the staff master the operation control technique. It is to be desired that OJT (On the Job Training) should be practiced in the new modernized beneficiation plant.

6.2 Operation Cost Reduction Plan

(1) Cost Reduction by Means of Instrumentation and Automation

Stabilization of the operation by means of instrumentation and control systems reduces losses. For example, it decreases the quantity of operator's work, saves labor, and simultaneously reduces reagents consumption.

(2) Energy Saving

For the purpose of energy saving, it is necessary to pause some machines, for example pump and flotatin cells, by changing process flow and arrangement of machines. Decreasing the number of operating machines means a reduction in maintenance expense.

(3) Cost Reduction due to the Improvement in Maquila and Ore-Purchasing System

The adoption of the all Ore-purchasing system reduces the loss time and complexity of individual treatment for each lot, allowing the operation rate to improve, and leading to further cost reduction. The office work is also simplified, and thus labor is saved.

(4) Rationalization of the Administration Department

It is necessary to improve the efficiency of certain business controls to carry forward labor savings by the installation of personal computers.

6.3 Improvement in Equipment Operation Rate

During the study of the equipment operating rate, a number of problems were identified which must be solved to improve this rate and have been outlined and clarified below:

- o Occurrence of accidental failures
- o The system of operation under the mineral processing commitment from more than one mine
- o Lack of water, unbalanced equipment, etc.

(1) The Plan for Reducing Accidental Failure Occurrence

Although details are described in maintenance considerations, first of all, it is necessary to produce a regular maintenance and repair system. In a mineral processing plant, generally, the operation rate should be almost 100 %, and the maintenance is planned so as to make that possible.

In the case of the CMF mill, no long term shutdown and maintenance plan was made. However, if a yearly maintenance plan and the proper execution system of routine management are established, accidental failures can be almost eliminated.

For this purpose, the installation of various measuring instruments, meters, alarm systems, etc. for early detection or discovery of any abnormality is effective.

(2) Maquila and Ore-Purchasing System

It seems this problem encompasses not only the equipment operation rate but also the operating efficiency of various devices in the metal recovery system have become major negative factors. To solve this, the best way is to accept all ores as custom ones.

Switching the present system to the all-custom-ore system allows the continuous operation, free from the current "state of interruption". Thus, the inefficient custom of waiting for a new opening of time for ore batch switching, should decrease losses from the original operation of shutdown, and can be expected to save time.

Also, the imbalance of operating conditions for each type of process, continuous processing of ores, some crude-ore blending of mixed processing, etc. allows the separate operation load factor of each device to be adjusted and allows each process to its maximum effectiveness. If an instrument for X-ray analysis and the determination of the instantaneous process condition within each step quickly, can be installed and utilized, it would be ideal.

To solve this problem, it is necessary to improve the recovery and operating efficiency of all devices as well as determine the equipment optimum operation rate. These synergetic effects can be expected. In addition, it allows the reasonable scheduling operations for establishing a preventive maintenance system to contribute to the reduction of failures.

(3) Others

For the imbalance of equipment problem, the problem is that there is a dispersion in the load for each process, the previous item (2), "conversion to a custom ore system", seems to be one planned solution for use of software. One of elements of this problem solving is also proper regard for hardware to first match it to the ore-supply of each device. For example, it is effective to make the feeding into the grinding system stable and variable by installing constant controlled speeds and to perform the fine adjustment of the quantity of processing ore while seeing that the balance of the whole processes is attained. It is also effective to know the load condition of each process point and equipment by installing a variety of instruments.

6.4 Improvement Plan for Maintenance

To perform the continuous operation in the mill, first of all, it is indispensable to eliminate risk in every aspect of equipment. To do so, it is essential to introduce a positive preventive maintenance system.

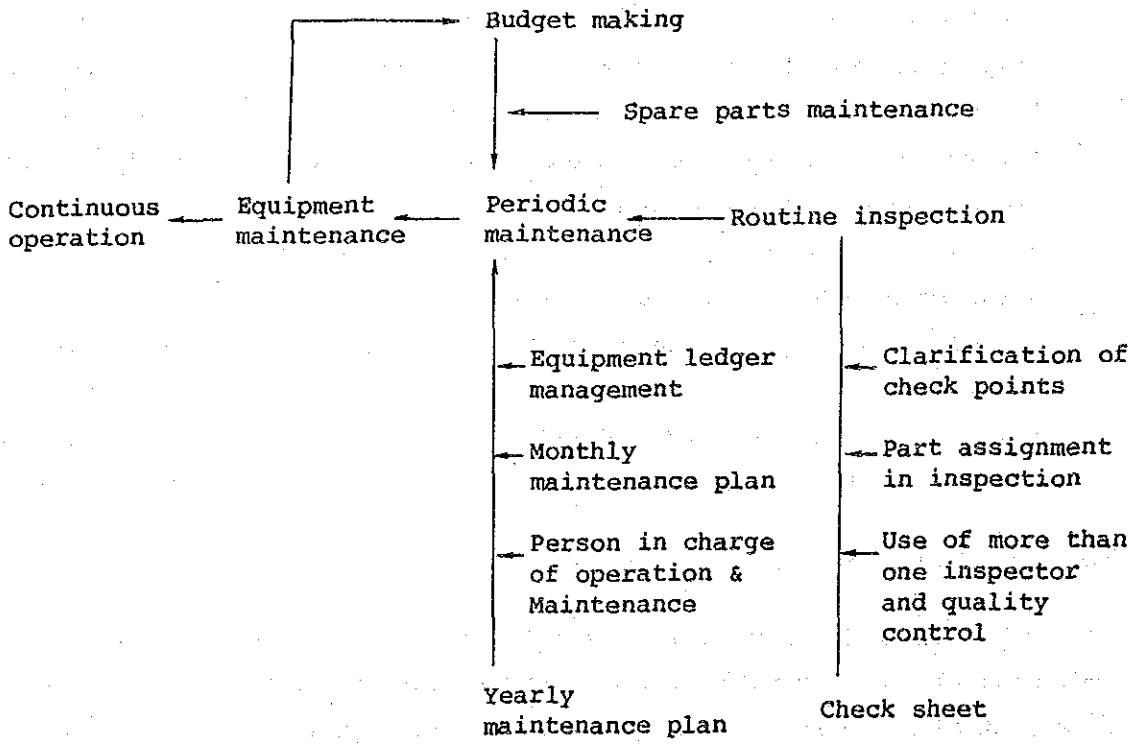
Considering the wide gap between this plan and present maintenance conditions, it would to be difficult to improve the system immediately. However, we would like to propose the following interium improvement plan for maintenance with the hope that the establishment of an ideal maintenance system in the future is be considered.

(1) Summary of the Maintenance System

At present, at each mill, the date for shutdown and maintenance is not formally set, and except during holidays, unless a failure occurs, maintenance of equipment is not done and the operation is continued. In many case, every time a failure occurs, the related equipment and the process is stopped to repair it. That brings about inconvenience and loss of the equipment operation rate.

To improve this, it will be necessary to execute a shutdown and maintenance periodically for peak performance of the operation to the full potential of the equipment.

The graphic display of measures required for the equipment maintenance is as follows:



(2) Planning of a Yearly Maintenance Work

For the main equipment in each process, a yearly maintenance plan is made. This is used to perform inspections of the expendable parts or the like at a proper interval on the basis of the repair records kept from the past. To organize the plan management, it is necessary to prepare a ledger of all pieces of equipment, so as to accumulate data such as their mfgr. specifications, repair records, serial numbers, etc. It is desirable that this ledger be prepared for all equipment being used in the plant, if possible.

Execution of a periodical inspection and maintenance plan for the main equipment to prevent 90 % of all major failures. In addition, this allows for the inventory of special parts for scheduled replacement and additional spare parts prepared in advance, resulting in improvement in every aspect of parts-procurement and resulting in a budget for maintenance cost be intentional and well-balanced for each month.

The equipment ledger will become the basis of the maintenance plan and is effective also for the estimation of the average life of expendable parts, the improvement of areas where frequent failure occurs, or the inventory management of spare parts.

(3) Enforcement of Routine Inspection

The periodical maintenance of main equipment requires technical knowledge and the experience of a person in charge of maintenance. However, it is the strict enforcement of routine inspection that supports this and makes a favorable daily operation possible.

The routine inspection must be practicable without requiring any advanced skill so that the foreman in charge of the operation management or even a worker can do it. In such a practice, it is very effective to prepare and make the most of a checksheet. For the items of the checksheet, such indication that can with certainly check the quality of the end product of the device should be checked, and such terms of expression that state concretely and simply should be used. As an ideal format, one that can be expressed by numerical values is

desirable, avoiding to the utmost a format that brings about the personal differences in judgement such as "non-defective/defective" teminology. This data will effectively be used later as the basic information for device failure analysis, the elapsed-time change of a condition, or the improvement of a device or process. Until a variety of measuring instruments are installed, it should be made a rule to record events even if "defective/non-defective" terminology is used for each process and device on the checksheet on the daily report log.

The routine inspection should not be performed by only one specified person in charge. It is important that the observation assignment be made for each shift of the operation, and more than one person perform it with a common judgment reference. All workers need to make an effort for the early discovery of abnormalities by executing a double or triple check. The certain execution of this observation work is not only effective in the maintenance of favorable operation, but also will produce pride and respect for the increased level of each inspector's knowledge on a device and his skill and the enhancement of his concern for the equipment.

(4) Summary

Establishment of a maintenance management system and raised consciousness of workers, not the simple maintenance of the repair system, provides the expectation of an improved effect such as the material study of expendable parts, the improvement in organization, the use of common expendable parts for each device, as well as the enhancement in the entire stability of operation. In general, equipment with a high rate of failure and the reasons for failure are limited. As the records of repaired devices and replaced parts become clearer, areas of concern will become obvious. Repeated study of equipment failure and ideas to improve procedures result in further fulfillment of the total maintenance system and cost reduction, leading to further improvement.

For reference, examples of the maintenance yearly plan table, equipment ledger, daily operation report (checksheet), etc. are appended (see Table 6.4.1 to 6.4.4).

6.5 Improvement in Maquila and Ore-Purchasing System

To solve problems in the present condition, the following improvement plan is suggested:

(1) All Ore-Purchasing System

In this system, ore is tested for quantity and grade at the time of acceptance (crushing process), and the price for the ore calculated under a standard price sheet is paid to each mine. The conditions for the price should be very specific and simplified.

(2) Processing System

Whether the ore in each mine is processed in a mixed state or singly (without being mixed) should be selected freely according to the circumstances at the time. In either case, it is not necessary to individually distinguish ore or its component products (concentrate) for each mine (the continuous operation is possible), and great recovery and cost reduction can be expected.

(3) Fundamental Beneficiation Results (Annual Production Plan)

On the assumption that ore in each mine is processed in a mixed state, or continuously and as a whole, the annual production plan is made, while on the basis of the operational results in the past and the test results of mineral processing in the lab, a monthly average result of mineral processing is established. This result is desirable to be put together as a whole in a unit of mill. However, it is also possible to set up different results according to the number of ore types.

(4) Price for Metal

For the metal paid by the refinery for each refining, the overall recovery rate is calculated by the refining recovery factor and on the ore-sale conditions for refining multiplied by the beneficiation recovery rate, which is decided according to the actual results of the production plan.

Each metal contained in ore is bought based on this overall recovery rate. For the official quotation of metal, the international market price at the time of buying is used.

(5) Lower Limit Grade for Crude Ore

The lower limit grade for crude ore is set up for each metal to make the metal with ingredients lower than this grade unsalable.

(6) Beneficiation Cost

All the expenses accruing at the mill such as mineral processing operating cost, overhead cost, and depreciation expenses are included in the estimate as the mineral processing cost and deducted from the total metal price. In this case, the same amount of money per ton for ore in each mine is equally deducted.

(7) Concentrate Selling Expense, Refining T/C and R/C

Since T/C and R/C according to the concentrate marketing expense and the refining condition vary in proportion to the grades of lead, copper, zinc, etc. contained in crude ore, these costs should be deducted from the price for each metal from a proportional calculation of them based on the crude ore grades in the production plan.

(8) Refining Penalty

Since the refining penalty per ton (ore) is small, the fixed amount of money in terms of US$0.1 is used based on the actual result. After it is added equally to the mineral processing cost, this is deducted from the price for the metal.

(9) Income and Cost of Mill

When ore is bought in this custom ore condition, if the same operating result as in the production plan is achieved, the income and costs of the mill becomes nearly zero. Actually, however, the difference between the actual operating result and the production plan accrues as the margin or loss from the difference, so the balance should vary.

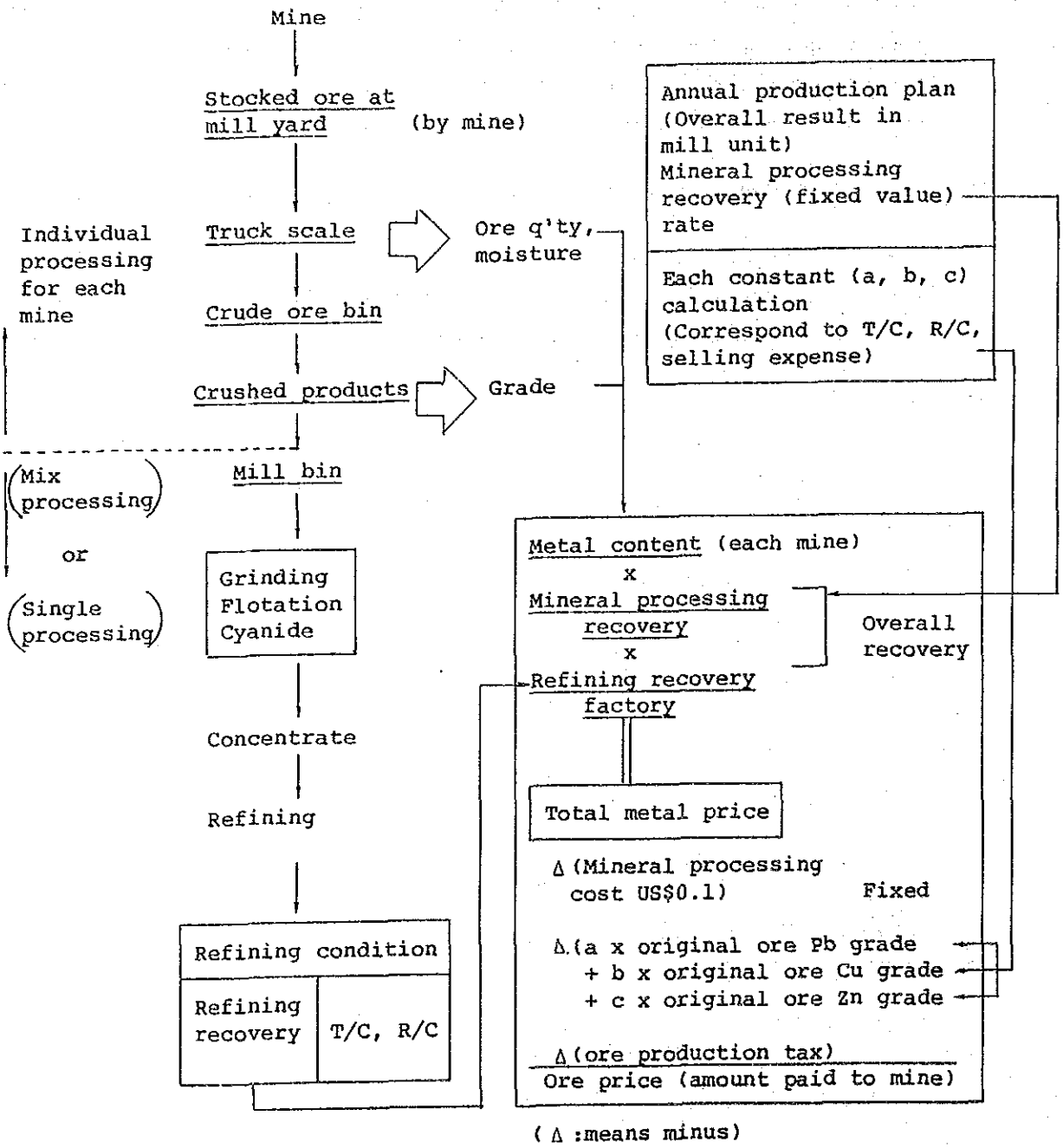
(10) Restudy of Condition

It is necessary that the annual production plan and an estimate of the mineral processing costs be revised every year based on the actual result during the previous year, and that on the basis of those figures, the condition of the mineral processing recovery rate or the mineral processing cost be readjusted as necessary.

(11) Individual Condition for Difficult-in-Processing Ore

For the ore that is extremely low in the mineral processing recovery and difficult to process, as an exception, after discussion with the individual owner of the mine, a single custom ore condition should be set up.

Ore-buying procedure and calculation method
of ore price in improvement plan



Example: Ore price calculation
(Refer to Chapter 8.5, Extension Plan in Barones Mill,
"Calculation of Price for Custom Ore")

6.6 Rationalization of Administrative Department

When improvement of management in each mill is carried out, one of the important factors is business rationalization.

It is an indispensable that condition be based on the operation. In this case, however, it is necessary to restudy the working environment that make up the business contents to provide management, the operations manager, or employees with rapid and timely information.

The result of our examination on the 3 mills was that all of the mills routinely make irresponsible operating decisions without making up a budget. Although some computers have been installed, the practical use of them is still inadequant. In view of this condition, points of improvement should be drastic budget & result orientated controls and the effective use of computers.

1. Budget and Result Orientated Controls

(1) Budget Preparation

The annual or half-year budget (in units of monthly amounts of money) is drawn up for each mill. Points to be noted in the budget making process are described later based on both documentation prepared and procedures set up on how to prepare those documents.

a. Raw material-purchasing budget
   Various raw material are purchased from many mines, but as grade varies and quantity purchased from each mine changes, the budget including the time frame for purchasing is made.

b. Processing plan
   Considering types of processing, mix or custom, should be determined according to the raw material-purchasing budget, or the considerations for major variation in factors of operation such as the equipment maintenance due to a shutdown, should be incorporated when planning the budget.

The cost control unit is set up for each administrative organization to compute the processing costs corresponding to its processing plan.

Based on the above items, the budget for income and cost is made.

c. Budget for administrative and auxiliary departments

The cost budget is made up for each department such as the administration, analysis, ore-acceptance,etc.

d. Budget for overall income and costs

Based on the income calculated from item b, this budget is assembled, to which the costs of items b and c are allocated.

e. Personnel plan

f. Fund plan

(2) Operation

At present, C.F.M., which is controlled by a centralized control system from the head office, the updated feedback control to each mill is impossible. Therefore, it should be required that the documentation on budget and actual results be prepared at the accounting department at each mill, they should be compared and analyzed in each mill, and if the results are lower than the budget, measures devised are prepared on a monthy basis. In this case, it is also desirable that related documents be sent to the head office to receive their approval and instructions.

(3) Measures to Execute Budget and Result Oriented Controls

At present, the number of persons in charge of administration in each mill is not sufficient in either quantity or quality.

To implement this, the installation of computers for making a variety of ledgers and their effective use are suggested.

2. Installation of Computers and their Effective Use

With the installation of computers and making effective use of them, the following are described later from the aspect of their installation effect: Determination for the replacement of the current work with the computer, selection of the items to be computerized in new work (the budget, results of control ledger), operation of them, calculation of installation expense, etc.

(1) Replacement of Current Work with the Computer

a. Statement for concentrate sales
b. Statement for custom crude ore
c. Receipt and payment statements for ore and concentrate
d. Receipt and payment statements for stock
e. Statement of salary
f. Fixed assets ledger
g. Statement of depreciation expense

(2) Items to be computerized in the new work

a. Budget comparison table by element
   (Refer to the document separately appended)
b. Income statement

(3) Operation

In the same way as pointed out in the flow chart for business rationalization separately appended, the "key-in" is made based on data from the side of on-site accounting. On the basic of the primary ledger outputed, the data required for the comparison table between the budget and results by each element, product receipt and payment ledger, and income statement is reentered. Since it is expensive to prepare a variety of ledgers in total with only the initial data input, existing software is to be used.

7. ECONOMIC EVALUATION OF CURRENT STATE

In this economic evaluation, for each beneficiation plant, we have shown items of sales and sales costs, outlines and general economic indices of sale's profit, general administrative expenses, selling expenses and ordinary profit, and lastly to obtain break-even points and marginal safety factors by calculating the ratio of variable expenses to the total amount of costs.

For both Guanacevi and Borones beneficiation plants, which are operating with deficits, we have some descriptions concerning the extent of income increase or expense reduction which both plants must attain to balance the income and expenditure.

CFM has not performed the revaluation of each plant's assets. With the recent severe inflation in Mexico taken into consideration, even management indices such as the turnover ratio of total liabilities and net worth; the ratio of ordinary profit to total liabilities and net worth, which are normally obtained from the balance sheet, seem to be somewhat vague. Therefore, we have decided to make this economic evaluation chiefly on the basis of the profit and loss statement. In addition, we have come to make no comparison of the profit and loss statement by fiscal year, and performed analysis chiefly on the basis of the last materials for the first half (January to June) of 1989.

(1) Parral Beneficiation Plant

Except for the fact that no revaluation of assets has been performed, this plant is operated very soundly and no important problems exist.

The break-even rate means that even the decrease in current sales at the rate of 32.52% does not cause deficit, and the state of business operation is still very stable under the present conditions. However, room is left for making an effort further to improve income and expenditure. Accordingly, if more reasonable management makes it possible to take steps such as a stable beneficiation fee for a certain period, the plant will contribute to the encouragement of the regional mining industry.

(2) Guanacevi Beneficiation Plant

This plant has been operating with a deficit except for 1984 and 1987.

In order to obtain break-even rate of sales (1,836 million pesos), the maquila fee must be raised to 40,200 pesos/ton (a u 67% increase), or alternatively the treated ore volume needs to be increased to 61,200 tons/term (a 34% increase) if the fee is kept at current levels. In the light of the mining potential for this area is limited and the treat-able ore volume will probably decrease in the future, each of the above ideas is overly optimistic. Accordingly, except for cost reductions by streamlining operations, no measures for improving income and expenditure are conceived.

That is, if the operation is drastically streamlined by reducing the total amount (718 million pesos) of material costs (511 million pesos) and the cost of electric power (207 million pesos) at the rate of 15% (108 million pesos), in addition to the one third (96 million pesos) reduction of the total personnel expenses (278 million peso), ordinary profit of about 30 million pesos would be obtained.

(3) Barones Beneficiation Plant

This plant has been obliged to continue operation with considerable deficit every year, and has the most difficult problems among the three beneficiation plants which we visited. For eliminating the deficit, the plant must increase income by raising the beneficiation fee.

However, since surrounding small mine-owners are politically powerful, any revision of the fee here has come into political question, which make economic viewpoints more difficult to solve.

The real cause of the deficit lies in the fact that the maquila fee and purchased ore beneficiation fee are limited to levels which are considerably different from the actual beneficiation costs (operating costs). Since the beneficiation fee is limited, the low grade ore which is difficult to treat is sent to this plant in great quantity.

The plant cannot raise its recovery rate in the beneficiation process because of superannuated equipment. As a result, the proposal for raising the beneficiation fee is not accepted by mine owners. These conditions seem to have formed a vicious circle.

In order to obtain the mine owners' consent for a raise of beneficiation fee, it is indispensable to decidedly take the same large-scale streamlining steps as those proposed for the Guarancevi Beneficiation Plant, and to perform a great renovation such as eliminating useless operations and also improving the recovery rate by constructing a beneficiation plant equipped with modern equipment.

8. BENEFICIATION PLANTS MODERNIZATION PLAN

8.1 Outline

The following four plans for modernization of beneficiation plants were developed:

a) Modernization of the existing facilities of Parral Beneficiation Plant
b) Modernization of the existing facilities of Guanacevi Benificiation Plant
c) Modernization of the existing facilities of Barones Beneficiation Plant
d) Plan for the establishment of a new beneficiation plant in Barones

(1) Beneficiation Capacity and Grade

For Parral and Guanacevi Beneficiation Plants, only modernization of existing facilities was planned, leaving the beneficiation capacity at the present level of 6,400 t/month and 7,800 t/month, respectively. As for Barones Beneficiation Plant, establishment of a new plant of a capacity of 3,900 t/month, as well as modernization of existing facilities was planned to raise the total capacity from the present level of 9,100 t/month to 13,000 t/month. The grade of the ore processed in Parral and Guanacevi Beneficiation Plants will be kept the same as the present grade, while the grade of the Ag ore processed in the newly built beneficiation plant in Barones is set about 15 g/t higher.

Beneficiation Capacity and Grade

	Beneficiation capacity t/month	Grade				
		Au g/t	Ag g/t	Pb %	Cu %	Zn %
Parral	6,411	0.74	325	0.6	-	0.2
Guanacevi	7,751	1.45	235	-	-	-
Barones (total)	12,956	0.57	170	0.2	0.1	0.5
Existing Facilities	9,056	0.47	175	-	-	-
New Plant	3,900	0.80	160	0.8	0.4	1.6
Barones (current) (actual record in 1989)	9,056	0.46	155	0.3	0.1	0.5

(2) Outline of the Modernization Plan for Existing Facilities of Parral Beneficiation Plant

Table 8.1.1 shows the outline of the modernization plans for the existing facilities of the three beneficiation plants.

The modernization plan for Parral Beneficiation Plant includes improvement of the dust collecting system to collect dust from the grinding plant, instrumentation to help stabilize operation, renewal of worn-out ball mills, and rationalization of the administration section to save labor. The total facility investment will be 1,493,000,000 pesos (US$563,000).

Carrying out modernization will result in a saving of about 5,100 pesos per ton of crude ore owing to improvements in the recovery rate for each kind of metal by 2 to 3%, and about 700 pesos per ton of crude ore owing to a reduction in sodium cyanide consumption.

The total depreciation and the interest will be about 2,300 pesos per ton of crude ore. Consequently, the balance will be about 3,500 pesos per ton of crude ore, the investment efficiency being 18.3% in ARR and 5.5 years in PB.

(3) Outline of the Modernization Plan for existing Facilities of Guanacevi Beneficiation Plant

The modernization plan for Guanacevi Beneficiation Plant involves the improvement of the grinding facilities to stabilize operation and save energy, rationalization and integration of the flotation system to save energy, development of the reagent facilities to stabilize operation and reduce the amount of reagents to be used, installation of a filter press to reduce the cost of concentrate dehydration and drying, and rationalization of the administration section to save labor. The total facility investment will be about 810,000,000 pesos (US$306,000).

The execution of modernization will result in a saving of about 3,500 pesos per ton of crude ore owing to improvements in the recovery rates for Au and Ag by about 2%, and about 2,700 pesos per ton of crude ore owing to energy saving.

The total depreciation and interest will be about 1,000 pesos per ton of crude ore. Consequently, the balance will be about 5,200 pesos per ton of crude ore, the investment efficiency being 59.2% in ARR and 1.7 years in BP.

(4) Outline of the Modernization Plan of Existing Facilities of Barones Beneficiation Plant

The modernization plan of existing facilities of Barones Beneficiation Plant involves system improvement employing the flotation-cyanidation straight processing method, in which a mixture of oxidized ore and sulfudized ore can be handled, instrumentation to stabilize operation and save labor, and rationalization of the administration section to save labor. The total facility investment will be about 612,000,000 pesos (US$231,000).

The execution of modernization will result in saving of about 3,000 pesos per ton of crude ore owing to improvements in the recovery rates for Au and Ag by 2% and 4% respectively, and about 1,200 pesos per ton of crude ore owing to a cut in the number of workers in the existing plant by 21.

The total depreciation and interest will be about 700 pesos per ton of crude ore. Consequently, the balance will be about 3,500 pesos per ton of crude ore, the investment efficiency being 63.7% in ARR and 1.6 years in PB.

(5) Purpose and Necessity of the Plan for Development of a New Beneficiation Plant in Barones

The purpose and necessity of development of a modern beneficiation plant adjacent to the existing Barones Beneficiation Plant is shown as follows:

a) Increase in the beneficiation capacity

The beneficiation capacity will be increased by 3,900 t/month, because the small and intermediate scale private mines in Zacatecas State expect to have a beneficiation capacity greater than that of the present Barones Beneficiation Plant.

b) Reduction of the cost of the existing plant

Since Barones Beneficiation Plant is now operating at a heavy deficit, it is necessary to reduce the operation cost by transfer of workers from the Plant and to reduce the general administration costs and fixed costs required for analysis and laboratories.

c) New plant with modern facilities

Since the existing facilities were quite old and the investment efficienty of development or overall facility renewal for the existing buildings would be low, it was determined that construction of a new plant with a set of modern facilities for the whole process of crushing, grinding, flotation, and concentrate dehydration would be beneficial.

d) Technical training and education

The OJT (On-the-Job Training) method was thought to be the best way to let personnel master the technical knowhow of operating modern facilities and modern operation management techniques. Consequently, the new plant is planned to be constructed as a model beneficiation plant to be used for training and education of personnel.

e) Achievement of a high recovery rate

When a modern automated plant with full instrumentation is operated by highly educated personnel and is administered by staff who have mastered advanced operation management techniques in which QC methods are adopted, and an all custom ore system and modern facility protection and maintenance system are introduced, operation conditions can almost always be optimized, resulting in a substantial increase in the beneficiation recovery rate.

f) Production of various kinds of concentrates

In addition to Au and Ag, high grade Pb, Cu and Zn are intended to be recovered at a high recovery rate. Recovery of iron sulfide (FeS) concentrates containing Au or Ag will also be considered in the future.

(6) Outline of the plan for development of a new beneficiation plant in Barones

A new plant (for crushing, grinding, flotation and dehydration) adopting Pb-Cu-Zn selective fotation will be constructed within the site of the Barones Beneficiation Plant. The beneficiation capacity is 150 t/day, or 3,900 t/month assuming 20 days of operation per month. The grade of crude or is set at 0.8 g/t for Au, 160 g/t for Ag, 0.8% g/t for Pb, 0.4% g/t for Cu and 1.6% g/t for Zn.

Table 8.1.2 shows the expected beneficiation results.

The expected recovery rates are 33% for Au, 76% for Ag, 73% for Pb, 86% for Cu and 68% for Zn. These are all higher than the previous values for the Barones Beneficiation Plant (average values for January through June, 1989); i.e. 21% for Au, 43.3% for Ag, 57.5% for Pb, 73.1% for Cu and 42.9% for Zn. The above expected rates are lower, however, for Pb and Zn in comparison with the recovery rates expected from batch tests for San Bernabe Mine; i.e. 68% for Ag, 91.9% for Pb and 89.6% for Zn.

8.2 Economic Evaluation of Mill Modernization Plan

(1) Method of economic evaluation

On the plant and equipment investment in both the modernization plan for the existing equipment in all 3 mills and the new plant extension plan for the Barones Mill, an evaluation was made by calculation of the Internal Rate of Return (IRR) by the Discount Cash Flow (DCF) method as a barometer of investment efficiency. IRR is the DR (Discount Rate) that can be determined by the following equation with the operating period:

$$\sum_{n=1}^{m} \frac{NCF}{(1+DR)^n} = 0$$

where NCF: Net Cash Flow
m: Operating period

(2) Prerequisite for economic evaluation

1) Production amount

In each mill, only the overall mineral processing result is calculated, based on the operational result for the period from January to June, 1989, and with ore from all mines and the total processing system combined. Besides, the sales amount when its product (concentrate) is sold to refineries in Mexico is regarded as the current production amount in each mill. This production amount does not always conform to that in the settlement of account. This reason is that in the case of consignment processing, the price for concentrate sales is not included in the production

amount of mineral processing, but only the consignment cost (corresponding to the mineral processing cost) becomes the amount of production of the mill. In addition, that is also the case of the ore purchase plan, where the quantity of concentrate to be sold from each mill to refineries does not always conform to the production result in connection with measured values of ore in, to measured concentrate out of the total inventory.

2) Refining Condition

In calculation of the refining condition of each concentrate, that of IMMSA, the major refining company in Mexico, was used as a standard.

3) Metal official quotation

For the metal official quotation, the following international metal price, the mean value per month for the period from January to June, 1989, was used:

Au: 384.119 US$/T.oz
Ag: 569.291 US$/T.oz
Pb: 633.944 US$/MT
Cu: 161.951 US¢/LB
Zn: 1819.577 US$/MT

4) Consolidated income and expenditure for the mines and a mill

In order to avoid the variation in evaluation due to the condition on which a mill accepts ore from each mine, that is, the difference in system, consignment or ore purchase plan, the economic evaluation was made by assumed estimation of the mining cost (the mean value in all mines in the district) and by trial calculation of the consolidated income and expenditure of the mines and a mill.

5) Costs such as mineral processing cost

For the present costs such as mineral processing cost, selling expense, administrative expenses, etc., the actual values for the period from January to June, 1989, was used, and after modernization, these costs were calculated based on those past figures and by using the estimated effects of improvement.

6) Interest rate

The interest rate for the plant and equipment investment was summed up as one of the non-operating expenses. In this case, this rate was assumed to be 5%, and it was set up on the assumption of financing from the international banking facilities such as IDB (Inter-American Development Bank).

7) Depreciation expenses

Depreciation expenses were calculated over 10 years for mechanical equipment, 15 years for buildings & other construction and 5 per cent for residual value.

8) Exchange rate

The foreign exchange rate was calculated as 1US$=2650 pesos.

(3) Conclusion on economic evaluation

For each mill, IRR was calculated for the following three cases: Ag price standard case (the mean value of the actual international prices for the period from January to June, 1989: 569.281 US¢/T.oz), in the case of a 10% increase in the value of silver (630 US¢/T.oz) and in the decrease of silver value of 10%-down case (510 US¢/T.oz).

Further, in the extension plan for Barones Mill, IRR was calculated for the four cases, that is, for the two cases where the quantity of ore to be processed in the plant is 150 t/day and 200 t/day, and in

addition, for the 10% increase in Ag value case to the standard Ag price at 150t/day and the 10% decreased value of Ag case to the same also at 200t/day. For each case, the IRR in consolidation with the profit and loss of the existing equipment in Barones was also calculated for the above-mentioned four cases. All of them can be put together as follows:

1) Modernization of the existing equipment

		Parral existing	Guanacevi existing	Barones existing
Plant & equipment investment (thousand peso)		1,493,275	809,392	612,050
IRR (%)	Case A Ag = 569,281 (US¢/T.oz)	19.9	49.5	52.7
	Case B Ag = 630 (10% up)	21.7	51.5	54.4
	Case C Ag = 510 (10% down)	18.0	47.5	51.0

The results of the calculation are shown in Table 6.8.1 to 6.8.4. The IRRs in Guanacevi and Barones are high in investment efficiency (about 50%) in either case.

2) Barones extension plan

Q'ty of ore processed	t/day	150	200
	t/month	3900	5200
Plant & equipment investment (thousand peso)		16,025,000	17,628,000
IRR (%)	Case A (Ag price standard)	6.5	9.2
	Case B (10% up)	8.0	(not calculated)
	Case C (10% down)	(not calculated)	7.8

The results of the calculation are shown in Tables 6.8.5 to 6.8.8. In either case, IRR is low (10% or less).

3) Barones overall evaluation

The overall evaluation on the modernization plan and the extension plan for the existing equipment are as follows:

Q'ty of ore processed (t/month)		12,956	14,256
Plant & equipment invesmtment (thousand peso)		16,637,050	18,240,050
IRR (%)	Case A (Ag price standard)	8.5	10.7
	Case B (10% up)	9.8	(not calculated)
	Case C (10% down)	(not calculated)	9.2

The results of the calculation are shown in Tables 6.8.17 to 6.8.20. In either case, IRR is low (10% or less).

9. CONCLUSION AND RECOMMENDATIONS

9.1 Modernization of the Present Equipment in the Three Beneficiation Plants

(1) Parral beneficiation plant

Seen from the viewpoint of mining potential the plant is promising in that there are tremendous ore reserves with the oxide ore still left, the sulfide ore barely exploited while the grade of ores is high as well as unchanging. Mining is being well operated and a steady ore supply will be possible for a long term.

Economically it is important to properly implement depreciation while reappraisal of assets being made and to perform maintenance of equipment and investment for renewal.

Modernization intends to curb deterioration of the equipment, improve production efficiency, stabilize operation, ameliorate working conditions and attain labor saving on the assumption that ore treatment of 6,400 t per month will be attained with the ore grade: Au, 0.74 g/t; Ag, 325 g/t; Pb, 0.2%, Zn, 0.2% and with improvement of beneficiation recovery up to; Au, 67.20%; Ag, 68.25%; Pb, 52.5% and Zn, 47.25%.

An investment in

a) replacement of ball mills,
b) full installation of dust collectors in the crushing processes,
c) some instrumentation of the equipment and
d) rationalization of administrative department

amounts to Mex $1,493 million (US$563 thousand) and this reduces the cost of ore treatment by Mex $3,556 per ton, which results in an profit of Mex $8,844 when added to a present ordinary profit of Mex $5,288 per ton, where IRR is 19.9% (but 18.0% when the market price of silver is lowered by 10% and 21.7% when it is raised by 10%), ARR 18.3% and PB 5.5 yr.

Conditions of investment:

a) The market prices of metals employed are the average values of the international market prices from January to June 1989.

b) The smelting and refining conditions on which sales of concentrates are based are in accordance with IMMSA (major mining and smelting companies in Mexico).

c) An interest of 5% was based on the premise of loans from the international monetary institutions such as US State Development Bank.

d) The terms of depreciation employed were 10 years for machinery and 15 years for buildings. The residual value employed was 5% and the depreciation was by straight-line method.

e) The exchange rate between US$ and Mex$ was based on 1$ = Mex$2,650.

f) The income increment (due to improvement in recovery) equivalent to the amount of investment plus the cost decrement (due to cost reduction in beneficiation expenses and administrative expenses) is the sum of gains by improvement, on the basis of which Internal Rate of Return (IRR) was obtained by Discount Cash Flow (DCF) method.

g) Accounting Rate of Return: ARR (%) =
[sum of gains by improvement - (depreciation + interest)] /sum of investment

h) Payback Period: PB = 1/ARR expressed by year.

i) Sensitiveness has some factors such as beneficiation recovery, ore grade, etc. Of them we employed the market price fluctuation of silver, the bands of fluctuation being made to 10% above and below the average value 1). This condition is the same with each beneficiation plant.

(2) Guanacevi beneficiation plant

Seen from the viewpoint of mining potential, ore supply to the plant mainly consists of residual ores and low-grade ores after having thoroughly exploited both oxide and sulfide ores. The ore reserves are being exhausted. Owing to new mining in Santa Cruz mine, the

required ore supply would be kept for coming two years but in the future it is necessary to further secure the ore quantity through prospecting in cooperation with CRM.

Economically, a decline in the quantity of ore treatment is anticipated and an increase in sales cannot be expected. Rationalization of operation is essential thus to attain drastic cost reduction. A reduction in the sum of labor cost by a third and that in electrical power and material costs by 15% will balance revenue and expense.

Modernization intends to maintain equipment, save energy, stabilize operation, reduce expenses and rationalize office work on the assumption that ore treatment of 7,751 t per month will be attained with the ore grade: Au, 1.45 g/t; Ag, 253 g/t and with enhancement of gold and silver recovery to about 80%, respectively, through modernization.

An investment in

a) installation of filter presses
b) some improvement in grinding processes
c) full preparation of reagents
d) rationalization of floatation processes and
e) rationalization of administrative department

The capital costs amounts to Mex $810 million (US$306 thousand) and this reduces the cost of ore treatment by Mex $5,155 per ton, which results in an profit of Mex $1,340 from current operation after having making up the present deficit of Mex $3,815, where IRR is 49.5% (but 47.5% when the market price of silver is lowered by 10% and 51.5% when it is raised by 10%), ARR 59.2% and PB 1.7 yr.

(3) Barones beneficiation plant

Seen from the viewpoint of mining potential, oxide ores are nearly in the final stage of exploitation while sulfide ores being scarcely exploited. In this region even low-grade ores that are unprofitable in other regions are being mined because of low beneficiation fee. Long-term ore production may be expected but the fluctuation in ore quantity and grade is likely to happen influenced by the construction of private plants.

On January 1989, CMF raised the beneficiation fee to Mex $30 thousand per ton ore (ore purchase: US$13), but only in Barones plant fee is suppressed to Mex $16.5 thousand (ore purchase: Mex $17.5 thousand). In the first half year of 1989 the income from current operation was Mex $5,288 per a ton of treated ores in Parral and the loss was Mex $3,815 in Guanacevi and Mex $15,799 in Barones. But if Barones plant was operated at the beneficiation fee similar to that of other plants, the loss would be Mex $1,990.

To make up the deficit not only revising the fee of beneficiation but also operational improvement is necessary. As a means of modernization a plant enlargement with the newest equipment by utilizing effective capital is required to improve recovery as well as greatly reduce operation costs.

The beneficiation plant is not fully operated with mine output suppressed and ore stock in the mine increasing. Ores with a high grade and exploitable in large quantity are being treated in the neighboring CMF El Bote mine at a high beneficiation fee. In the medium-scale mines with large ore reserves, private beneficiation plants and leaching plants and private custom plants are being constructed. Due to such situation and the low beneficiation fee of Barones, low-grade and hard-to treat ores as well as ores of a small lot abound in this region so that the decrease of recovery and operation efficiency and deficit operation result. Amelioration of this condition is quite difficult to perform. There is no choice but to promote plant efficiency and increase recovery.

In conclusion, the enforcement of modernization plan and a raise of beneficiation fee from the present Mex $16,500/t to Mex $25,000/t should be done.

IRR in building a new plant is 6.5% at 150 t/d and 9.2% at 200 t/d, while IRR in the case of improvement of the existing plant plus building a new one is 8.5% at the former and 10.7% at the latter. The term of construction assumed is 2 years.

9.2 Recommendations for Modernization of Each Plant in Common

The fundamental means on which improving beneficiation recovery, reducing operation costs, promoting plant efficiency and improving maintenance are based are instrumentation, automation, establishing the system of preventive maintenance and mending and the adoption of all Ore-Purchasing system in place of the current combined system.

Instrumentation and automation are intended for a stabilized plant operation, where controls of beneficiation factors are necessary and accumulation of daily data are required to obtain the optimum conditions, thus the instrumentation such as recording continuous data being also needed. At the same time, training of operators and acquisition of control technology by staff are essential.

Establishment of maintenance and mending systems are intended for optimization of each machine load, reduction of expenses, optimization of parts stock and the resultant betterment of operation efficiency. The following, therefore, are proposed: A daily check and checking with check sheet by more than one person, Introduction of an annual maintenance plan and utilization of maintenance books and Installation of failure detectors to lessen watchmen's load and thus prevent human errors.

A combined system of Maquila and Ore-Purchasing incurs waste of time and complex of work resulting in a low operation-efficiency. Conversion to the all Ore-Purchasing system enables the plant improvement and controlled beneficiation. In this system purchase conditions are properly revised monthly according to the past result of recovery and test result. Then including conditions of smelting and refining and sales expense, the ore purchase system is determined. Based on the classification such as oxide, sulfide, high grade, low grade and hard-to-treat, ores from each mine are mixed and treated separately according to the classes.

In the administrative department the following are proposed: a planned control system on the basis of estimated costs which makes it possible to take measures against abnormality and to prognose the future, and introduction of personal computers for the purpose of simplification, labor-saving and speeding-up of office work.

Summary:

The sum of the investment for modernization of the three beneficiation plants amounts to about Mex $20,543 million (US$7,752 thousand) (increased plan of Barones 200 t/d) and the total output (amount of ores treated) of the three plants increases from the present 23,218 t/month to 28,413 t/month with an increment of 5,200 t/month. Sales output increases roughly from the present Mex $20 billion/month to Mex $26 billion/month, an increment being 30%.

A great amount of improvement in revenue of the three plants will be attained, the sum being Mex $165 million/month, and this is a conspicuous contribution to mining production in the three regions.

In order to further promote and Mexican private medium and small scale mines, CFM should promptly take measures for modernization as proposed in the present investigation and also start the new construction in the three plants while necessary financing being made.

We sincerely hope that the achievement of modernization to be performed in the three beneficiation plants would act as a model case and hence a sophisticated beneficiation technology would extend throughout the nation, thus contributing to the development of mining industry of the whole Mexico.