Foreword

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Mining industry provides the necessary supply of valuable metallic and non-metallic materials for global consumptions. Metallurgical industry processes the ore for distribution to different industrial plant. The existence of these two significant industries is imperative to the benefit of the general public, especially here in the Philippines where the land is rich of mineral resources.

The three technical papers presented in this issue feature some of the important applications in the field of mining and metallurgical engineering. The two articles written by Professor Enrique Ostrea tackle the potential benefits of the gold refinery and the proposed metallurgical treatment in the production of pig iron for steel manufacturing in the country. Professor Ostrea, who played an active part in the development of mining and metallurgical engineering in the Philippines, strongly believed that these kinds of undertakings will be profitable and essential to the government. Unfortunately, we are not able to fully capitalize this kind of proposition. The article written by Dr. Manolo Mena described the reduction behavior of nickel in high-iron.

The pioneering role of mining and metallurgical engineering in national development is inevitable. With the mandate of corporate social responsibility and the advocacy of sustainability, the mining and metallurgical industries will provide economic benefits and at the same time follow compliance in the other aspects at stake on the operation such as environmental, social, health and safety. It is therefore a challenge for every sectors involved; the government, the mining and metallurgical industries, the engineers, the local government units and the socio-civic organizations to fully maximize the use of our resources.

[*Contribution from the Division of Mineral Resources.*]

OUTLOOK OF GOLD REFINING IN THE PHILIPPINE ISLANDS

E. OSTREA AND V. ELICAÑO

INTRODUCTION

Production.—Gold production in the Islands has been increasing rapidly. A survey of the annual gold production for the past ten years reveals this fact.

TABLE I.

YEAR	WEIGHT OF FINE GOLD AND SILVER, GRAMS	VALUE, PESOS
1922	3,041,904	2,968,042
1923	3,712,138	3,422,054
1924	4,202,042	3,422,764
1925	5,060,534	3,984,099
1926	4,278,845	3,907,835
1927	3,421,499	3,407,977
1928	4,028,892	3,854,683
1929	8,152,104	6,851,246
1930	8,805,360	7,495,373
1931	8,681,211	7,594,215
1932	11,116,260	10,003,200

The 1932 estimate was obtained from the estimated monthly production furnished by the following mines:

Benguet Consolidated Mining Co., ...	₱300,000.00
Balatoc Mining Co., ...	343,600.00
Itogon Mining Co., ...	120,000.00
Panique Mining Co., ...	35,000.00
All others	35,000.00
Total monthly production	₱833,600.00
Total yearly production	10,003,200.00

According to the Bureau of Custom, the Philippines shipped to the States Gold Bullion weighing 439,072 ounces valued at ₱10,062,292 which tally closely to the above estimate.

Average Composition of Gold Bullion: Gold bullion is an alloy consisting mainly of gold, silver, and base metals, combined

in various proportions. From the production and average composition of the gold bullion produced by the leading gold producers as shown in table 2, its average composition is 540 parts gold, 341 parts silver, and 119 parts base metal for every 1000 parts.

TABLE II.

Mining Company	1932 Production Fine Grams	Fineness		
		Gold	Silver	Base Metal
Benguet Cons. Mining Co.,	5,194,956	575	325	100
Balatoc Min. Co., ...	6,775,692	500	406	94
Itogon Min. Co., ...	202,576	602	281	119
Panique Min. Co., ...,...	91,380	511	164	325
All others	91,380	511	164	325
Average	——	540	341	119

ELECTROLYTIC REFINING OF A 10-MILLION-PESO WORTH OF GOLD BULLION

Methods Used in Gold and Silver Refining: Gold and silver are refined by several methods, but those of commercial importance are: parting by the use of sulphuric acid and parting by the use of an electric current. The former was mainly used in Europe and in America during the latter part of the 19th century, but is almost superseded by the electrolytic process due to the following advantages:

1. Production of purer gold.
2. Saving of all platinum and other rare elements.
3. Non-production of obnoxious fumes.
4. Less cost of production.

At present, the electrolytic method of separation of gold and silver is used at the mints of the United States located in San Francisco, Denver, Philadelphia, and New York. For the purpose of estimating the cost, and electrolytic refinery consisting of the Moebious Silver Process modeled after that of San Francisco Mint, and the Wolhwill Gold Process modeled after that of the New York Mint, with a capacity of 10-million-peso worth of gold bullion, shall be considered. It shall be further considered.

A. That for the silver process in which direct current is used.

1. The anodes are:
   a. Size — 1½cm. by 7½cm. by 30cm.
   b. Composition — 300 parts gold 600 parts silver and 100 parts base metal.
   c. No. per tank — 66 anodes.
2. The cathodes are:
   a. Size — 0.13cm. by 7-1cm. by 37-1.2cm.
   b. Composition — pure silver.
   c. No. per tank — 66 anodes
3. The electrode distance is 3.75cm. apart.
4. The cells are: of stoneware 42cm. by 60cm. by 60cm. by 11cm. in size, and 12 cells used per silver cycle.
5. The electrolyte consists of:
   a. 3% silver as silver nitrate
   b. 2% fine nitric acid.
6. The voltage per cell is 1.38 volts.
7. The current density per square foot of anode surface is 6 amperes or 180 amperes per tank.
8. A silver cycle last 50 days of 8-hours per day.
9. The electrolyte is circulated by hard rubber pump.

B. That for the gold process in which pulsating current is used.

1. The anodes are:
   a. Size-1.4cm. by 8.3cm. by 17.8cm. approximately.
   b. Composition -875 parts gold, 100 parts silver and 25 parts base metal.
   c. No. per tank — 15 anodes.
2. The cathodes are:
   a. Size-0.034cm. by 8.3cm. by 25.3mm.
   b. Composition — Pure gold
   c. No. per tank — 18 cathodes.
3. The electrode distance is 3.3cm. apart.
4. The cells are of vitrosil or porcelain 27-1.2cm. by 31-1.2cm. by 43-1.2cm. in size, and 5 cells used per gold cycle.
5. The electrolyte consists of:
   a. 30 grams gold as gold chloride per liter.
   b. 10% fine hydrochloric acid.
6. The voltage per cell is 2.2 volts, pulsating. This is pro-

duced by a superimposed direct voltage of 1.2 volts on alternating voltage of 1.8 volts.

7. The current density per square foot of anode surface 496 amperes pulsating. This is produced by a superposed direct current of 333 amperes per sq. ft. on an alternating current of 367 amperes per sq. ft.
8. The gold cycle lasts eight days of 8-hrs. a day.
9. The electrolyte is circulated by a hard rubber pump.
10. 2.5 ounces of pure gold is used as hook per cell.

C. That the copper process in which a direct current is used:

1. The anodes are:
   a. Size — 1.4cm. by 8.3cm. by 17.8cm.
   b. Composition — copper 50% : zinc — 30% lead 10%., iron — 5% ; silver, platinum, gold — 5%.
   c. No. per tank — 15 anodes.
2. The cathodes are:
   a. Size — 0.13cm. by 8.3cm. by 25.3cm.
   b. Composition — pure copper.
   c. No. per tank — 18 cathodes.
3. The electrode distance is 3.3cm. apart.
4. The cells are of lead lined wooden tanks 37-1.2cm. by 31-1.2cm. by 43-1.2cm. in size and 3 tanks per copper cycle.
5. The electrolyte consists of:
   a. 3% copper as copper sulphate.
   b. 4% fine sulphuric acid.
6. The voltage per cell is 0.6 colts.
7. The current density per sq. ft. is 10 amperes.
8. The copper cycle lasts 20 days of 8 hours per day.
9. The electrolytes is circulated by hard rubber pump.

ITEMIZED STATEMENT OF SOURCES OF ESTIMATING COSTS

A. Material and Equipment
B. Operating Expenses.
   1. Power
   2. Acid
   3. Miscellaneous
   4. Amortization
   5. Labor and superintendence

A. Material and Equipment

1. Materials needed:

(1) At P20.00 per kg. of silver, the amount needed for cathodes, alloy and electrolyte is P69,098

(2) At P1.32923 per gram of gold, the amount needed for cathodes, hooks, and electrolyte is P43,745

Total cost of materials is P113,843

This amount of material can be replaced as soon as the first batch of refined gold and silver is finished.

2. Equipment:

(1) The silver Process:

It includes: 15 stoneware tanks, 25 iron moulds rubb covered steel rods, rubber pumps, tubings, 1 rolling mill and motor, 1 motor generator, 1 switchboard control, 1 regulator, with an aggregate value of ..... P10,983.91.

(2) The Gold Process.

It includes: 12 vitreosil or porcelain tanks, 36 iron moulds, rubber covered steel, rubber pump, rubber tubings, 1 rolling mill with motor, 2 sets of 3-units 6-bearing motor generator, I switchboard regulator with an aggregate value-of P10,417.25

(3) The Copper Process:

It includes: 6 wooden lead lined tanks, 3 iron moulds, lead sheets with an aggregate value of P170.00

(4) Accessory equipment:

It includes: 1 bullion balance, 1 assay balance, 1 tilting furnace, 2 assay furnaces, 1 sampling machine, 1 hand roller, 1 distilling apparatus, 2 oil burners, 1 set of platinum parting basket, 1 hot plate 1 optical pyrometer with an aggregate value of ..... P28,012.99.

Allowing 50% as a factor of safety for any changes in prices, the total cost of equipment is ..... P42,019.49.

It is interesting to note that our government has in store all these equipment with the execption of few parts and which aggregate value is only ..... ₱8,450.00.

B. Operating Expenses:

1. Power:

   At ₱0.10 per kw. hr., 94% current efficiency, 70% energy efficiency, the total energy consumed are:

(1) For the Silver Process	₱1,020.84
(2) For the Gold Process	1,716.00
(3) For the Copper Process	46.00
(4) Accessories	1,590.00
Total cost for power	₱4,373.10

2. Acid:

(1) Nitric Acid at ₱0.275 per kg.	₱2,859.72
(2) Hydrochloric acid at ₱0.075 per kg.	291.60
(3) Sulphuric acid at ₱0.046 per kg. ...	5.16
Total cost for acids	₱3,156.48

3. Miscellaneous:

(1) Fuel for assaying	₱270.00
(2) Fuel for casting and melting	212.00
(3) Gas for heating hot plate and for making distilled water	795.00
(4) Crucible for melting	856.00
(5) Fluxes	384.00
(6) Other reagents	164.00
Total cost for miscellaneous	₱2,681.00

4. Amortization on equipment cost.

   If equipment lasts 10 years and its cost earns 4% compound interest, the amortization per year on ₱42,019.49 will be ₱3,819.95, and its interest at 10% simple interest is ₱4,201.95 or a total of ₱8,021.90 per year.

5. Labor and Superintendence per annum:

1 Superintendent and assayer	₱4,000.00
1 Asst. Supt. and assayer	3,600.00
1 Melter	1,800.00

1 Attendant, refining room	1,200.00
1 Mechanic, electrician, and roller ...	1,200.00
1 Helper refining room	600.00
1 Helper melting room	600.00
1 Helper assay room	600.00
1 Helper rolling room	600.00
1 Clerk-accountant	1,200.00
1 Messenger	360.00
Total cost of labor and superintendence	₱15,760.00

Allowing 50% as factor of safety on power, acid, and miscellaneous for changes in prices and efficiency, the total operating cost per year is ..... ₱39,127.77

Rate of Charges and Income:

Rate of Refining Charges by U. S. Mint:

The rate of charges prescribed by the Director of Mint effective July 1, 1925 are as follows:

TABLE III.

Gold Content. Thousandths	Charge	Base Contents. Thousandths	Additional Charge
		Up to 50	0.00
¼ to 250	0.01	In excess of 50-150	0.005
250¾ to 500	0.02	Above 150, for each or fraction thereof (additional to ½ cent base charge)	0.01
500¼ to 949¾	0.04	.....	—
950 to 991¾	0.02	No allowance for silver content	—
992 to 1000	—		

Since the average of our gold bullion is 540 fines gold, 341 fines silver, and 119 fines base metal, the charge will be ₱0.09 per gross ounce or fraction thereof.

Total cost paid by our mining companies per oz. of gold bullion treated:

The different mining companies, however, pay, besides refining charges, for transportation, insurance, commission and interest. The amount incurred by each item per gross ounce of bullion treated, as furnished by this different companies are as follows:

TABLE IV.

Company	Refining Charges	Transportation	Insurance	Commission	Interest	Total Cost
Benguet Cons. Mining Co., .	0.085	.0450	"Unable to furnish"			0.1854
Balatoc Min. Co., ...	0.084	.0453	.0450	Nil	—	0.1338
Itogon Min. Co., ...	0.105	.0892	.0417	Nil	0.17	0.14059
Panique Mines	0.116	.06	.½ of ½% on declared value.	⅛ of ½% base on mint return.	½ of 1%	0.40*

It includes cable and telegraph charges at 1-centavo per ounce of gold bullion.

Income:

Using the above rates as rate of charges per gross of treated, the income realized on the refining of 13,500 kg. or 432,000 ounces of gold bullion are as follows:

TABLE V.—INCOME AT VARIOUS RATE OF CHARGES, PESOS.

CHARGES PER OUNCE	INCOME	EXPENSE	ESTIMATED PROFIT
0.1338	57,801.60	39,127.77	18,673.83
0.1854	80,092.80	39,127.77	40,965.03
0.40	172,800.00	39,127.77	133,672.23
0.4059	175,348.80	39,127.77	136,221.03

Assuming that the amount paid by the Benguet Consolidated Mining Co., be the average charge per ounce of bullion to be refined, the proposed electrolytic plan will realize an annual income of almost ₱41,000.00.

SUMMARY

Our estimated gold production for 1932 reached 13,500 kg. in round figures. Its average fineness as furnished by the producers is 540 parts gold, 341 parts silver, and 119 parts base metal. An electrolytic gold refinery with a daily capacity of 45 kg. working 300 8-hour days a year, can be maintained. This plant, using the Moebius Process for refining the silver, and using the modified Wohlwill Process for refining the gold, requires the following initial expenses:

1. Gold and silver for alloying, cathodes, and electrolyte ..... ₱113,843.00
   (Note: This amount is negligible if the refining is undertaken by the government because the gold and silver bullion deposited in its treasury can be used for this purpose, and then subsequently returned.)
2. Equipment ..... ₱42,019.49
3. Yearly operating expense ..... ₱39,127.77

The gross income for treating this bullion, assuming that

the present cost of ₱0.1854 per ounce paid by the Benguet Consolidated Co., be the rate of charge per ounce of bullion treated is ₱80,092.80, leaving an annual net profit of ₱40,965.03.

Aside from the pecuniary profit obtained from the refinery the following advantages favor the establishment of a gold refinery by the government:

1. The gold bullion will remain in the Philippines and not go to the United States as at present.
2. The gold bullion will eventually be the gold reserve for the currency of the Philippine Government.
3. Precious metals such as platinum and other rare elements are recovered and added to the annual income of the government.

CONCLUSION

The authors believe that the outlook for the establishment of a gold refinery to be undertaken by the government will be profitable and very essential.