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NEW TECHNIQUES IN THE USE OF SPANISH PYRITIC ORES AS RAW MATERIALS

By

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1. The pyritic minerals, defined as those metallic ores which contain iron sulphide with other more or less complex metal sulphides, have always been regarded internationally as an important non-ferrous metal ore.

Moreover, oxidation by roasting the pyrite content has been the basis of sulphuric acid production in many countries. In 1971 28% of all sulphuric acid was obtained from this raw material. Although this proportion of the world total has decreased (in 1961 it was 36%), in absolute terms usage has increased during this period by about 13%. In some of the most important industrial countries the trend is continuing and in varying degrees it is the most important raw material for this branch of the chemical industry. Japan, Russia, Sweden, Italy and Spain are examples of this fact.

The sulphur of the pyritic ores is even more valuable when the sulphurised concentrates of the non-ferrous metals obtained in hydrometallurgical processes are smelted. In 1971 the sulphuric acid obtained by recovery of this sulphur amounted to 22% of the world total.

In short, pyritic ores are today a raw material which, taken as a whole, account for 49% of the world production of sulphuric acid, 22% of the production of non-ferrous metals (chiefly Cu, Pb and Zn), and also other metals which, although smaller in quantity, but are of strategic importance, including the most precious (Au and Ag). The countries which have their own resources of these ores maintain a permanent research force for their optimum development.

It is the object of this paper to review the present state of these techniques, to analyse some of those which have emerged in the last few years and also to make a contribution to the subject by explaining the general outlines of the present and future treatment of Spanish ores.

2. During the period in which the chemical industry regarded pyrite almost solely as a raw material for its sulphur value, that is to say, between 1890 and the decade 1960-70, the method of treating the ore differed somewhat from country to country.

In Europe (both West and East) ores with a high content of non-ferrous metals, obtained in the Mediterranean basin (Spain, Portugal, Cyprus, Turkey, Greece), were roasted in order to recover the SO_2 in the form of sulphuric acid or other derivatives and the residues were subjected to a process from which the non-ferrous metals were obtained. Chloride processes were used in plants in Western Germany, Sweden, Spain and Portugal, but there were several exceptions: in Sweden (where the ores were subjected to differential flotation in order to obtain the non-ferrous metals in the form of sulphur concentrates and pyrites very rich in sulphur), in Italy (where the minerals were pre-roasted so that the residues could be subsequently agglomerated for use as iron ore) and more recently in Western Germany, where they converted their Meggen minerals into an ore of metal concentrates by differential flotation.

In Far Eastern countries, particularly Japan, Australia and New Zealand, pyritic ores are subjected to hydro-metallurgical processes in order to extract their metal content and are later treated as sulphur ore.

Mention should be made of Japan, where integrated use of its mineral resources was achieved by original technology, the results of which made it possible to base all inorganic chemical development during the "Japanese miracle" on the country's own pyritic minerals.

On the American continent, particularly in the North (U.S.A. and Canada), pyritic ores have been very much a part of the non-ferrous metal industry. Hydro-metallurgical beneficiation (flotation, concentration, leaching) has produced a large proportion of the raw material for the smelting of copper, lead and zinc and, also, more concentrates of sulphur produced by roasting.

Finally, in African countries, where the consumption of sulphuric acid has remained at a low level for lack of full industrial development, the processes have chiefly tended to be used for metals and very specific methods were applied (sulphating contamination or leaching "in situ" for example).

Every country and every district had its own special way of treating its ores both because of its productive and industrial structure and because of the particular condition and specifications of its raw materials.

During this long period of 70-80 years, pyrites (both as crude ore or as material pretreated by metallurgical beneficiation) has always been an excellent material for competing with sulphur ores and also with elemental sulphur. Most industrial countries which have their own sources of pyritic minerals have used them very

successfully in their long and spectacular process of industrial development and, more to the point, are still using these processes as reliable sources of essential chemical products.

3. What new developments have there been between the mid 'sixties and today? Is there anything which is influencing in any important way the world structure of pyrite production and treatment as we have described it above?

The most remarkable event has been the exponential growth of population and the parallel degree of industrialisation of the world. Although there does not appear to be any direct connection between this development and the subject with which we are concerned, it is increasingly necessary to look at the world as a "Dynamic System" in which the interrelations of factors fundamentally influence the overall results The exponential growth of the population and of industrialisation have resulted in increasing consumption of energy in all its forms (fuel, fossil, natural gas, hydroelectric, nuclear) and as an inevitable consequence, at the present time, a world consciousness of:

a) The limits of resources of energy and raw materials available.

b) Pollution and deterioration of the environment.

Although we are only in the early teething stage of attacking these problems as a whole, the tendency in the last few years has been to deal with point b) with the following consequences:

- desulphurisation of natural gas
- purification of the light and medium petroleum fractions
- subsequent limitation of the S content in fuel oil fractions
- more and more regulations to purify stack and residual gases
- growing costs of production throughout the world because of the additional costs of atmospheric control.

The first sign of these trends was a surplus of residual elemental sulphur, production of which is related to the energy consumption and political character of each

country and consumption of which for industrial purposes is governed by purely technical and economic factors. In as much as these factors are different, as they are today, the disequilibrium will tend to keep down the price of elemental sulphur which, allied with other advantages of a qualitative and technical nature, leads to a preference for its use as a raw material for the production of sulphuric acid.

Although it is not the main subject of this paper, it is appropriate to ask here: first, is this tendency as clear as has been stated by some authors and, secondly, is it so permanent as to be regarded as irreversible?

In our opinion, which will be expounded in more detail in the following sections, the growing world-wide need for non-ferrous metals, due to factors comparable to those which caused the exponential increase in energy consumption and the production of elemental sulphur, makes it essential to have a growing (and equally inevitable) production of high quality pyrites at low cost which, consumed "in situ", will continue to produce a cheaper sulphuric acid than that derived from elemental sulphur.

The second question is a real challenge to all industrialists throughout the world. Without attempting to probe too deeply into so difficult a subject, we should like to submit for the reader's consideration a number of premises which have helped us in forming a subjective opinion on the matter.

- World-wide industrial development was based upon the concept of "cheap energy". This applies particularly to very highly developed countries, which today are the world leaders.

- The scarcity we have mentioned of "fossil fuels and natural gas" in these countries, the rising cost of prospecting for and producing these fuels in the countries of origin, the escalation of fuel prices on the international market (over 75% of the total) and the political factors prevailing in the field of international energy, point to a future of "expensive energy".

- The costs of desulphurising petroleum fractions (light, medium and heavy), industrial effluents and end products increase these energy costs even further. The residual sulphur obtained is sold at prices lower than the cost of production. It is the "energy" factor which absorbs the

difference in price, increasing its sale price to the final consumer.

- This situation cannot go on indefinitely. At any time the "energy" factor, subjected to an irresistible pressure of inflation, will be brought under control in order to prevent it from rising and then today's by-products (including elemental sulphur) will be quoted at their real prices and not at today's subsidised prices.

- The result of this situation will be that despite a surplus on the market (when pollution control increases all over the world) the price of elemental sulphur will rise, because it will be determined by the "energy" factor.

On the other hand, the continued presence on the market of a plentiful commodity such as elemental sulphur, at low cost, will carry with it the benefit of increased use of that commodity in view of its highly valuable structural properties which will increase the likelihood of a re-examination of the "energy" factor referred to.

When will this reversal of trend take place? Insufficient information is available to enable me to forecast this. There are so many recurrent factors that it is difficult to suggest a date with any certainty. Nevertheless, if it is assumed that everything happens in accordance with the extrapolation of a past series of these factors, and therefore neglecting unforeseeable factors which would materially modify the underlying situation, our prediction would be around 1976-8, i.e. in less than ten years from now.

The reaction of the various countries between the years 1969-72 has depended upon whether they are importers or producers of raw materials.

In general, a number of areas have become consumers of elemental sulphur but those countries which have large sources of pyrites have built up large centres of production and consumption of sulphuric acid near their mines, with the inherent advantages of integrated industrial complexes, economies of scale and integrated utilisation of the minerals. This sound basis of production is and will be at any time a guarantee of security and independence for the local chemical industry. This has happened in the following countries which have a substantial degree of industrial development: Russia, Japan, Italy, Sweden, Spain, Canada, New Zealand and Roumania. There are other examples.

It is an undoubted fact that, in addition to purely local factors, leaders of industry have taken into account the economic and strategic factors which are briefly dealt with in this paper.

4. It is desirable to establish some very clear basic principles in order to understand the reasoning governing our considerations.

- Elemental sulphur - about 90% of this is used for the production of the mineral acid used in industry, i.e. sulphuric acid

- 100% of pyrites (except those subjected to hydrometallurgy solely for recovery of the metals contained in them) is used for the manufacture of sulphuric acid

- Therefore the competition between pyrites and elemental sulphur is in the role of raw material for the production of sulphuric acid

Any study of this competition on present and/or future bases must assume:

- the same cost price for the acid

- profitability equivalent to capital invested

- economic compensation for possible disadvantages due to the different characteristics of the raw materials

In a general investigation it is not possible to take into consideration the particular case of small sulphuric acid plants at particular places. Generally speaking, for obvious reasons of economic and industrial strategy, the new sulphuric acid plants have the following characteristics:

- They are situated in a centre of substantial sulphuric acid consumption (for example, Rotterdam, Hamburg, Tokyo harbour). They have to import their raw materials.

- They are situated near large production centres of raw materials (for example, Fallonica, Louisiana, Coatzocoalcos, Okayama, Tomakomai, Huelva).

- They have a minimum capacity of 500 mtpd and frequently, a more probable capacity of about 1000 mtpd.

- In their neighbourhood there are groups of industries using their products and/or by-products.

In order to arrive at a quantitative estimate of the competition between the two raw materials and their future prospects, Tables 1 and 2 have been prepared; these summarise the structure of the production costs of sulphuric acid, starting from pyrites and elemental sulphur, and the intrinsic value of a ton of pyrites under different market conditions.

Table 1 was drawn up on the following bases:

- The raw materials were left as an unknown quantity, since they are a function of their corresponding market price. If 0.367 m ton of sulphur contained in pyrite is consumed and $\underline{x}$ is the nett price (i.e. after valuing the by-products of the pyrite at market price) and 0.338 m ton of elemental sulphur is consumed per m ton of 100% H_2SO_4 and $\underline{y}$ is its price in the consumer's factory - then in one case the raw materials would cost 0.367x, whereas in the other they would cost 0.338y.

- The capacity of the plants is 1000 mtpd 100% H_2SO_4.

- The investment ratio is 2.6 between the pyrite plant and the sulphur plant.

- The difference of invested capital is regarded as producing an annual interest of about 9% to the industrialist who constructs the plant using elemental sulphur.

- A cost of U.S.$ 0.5 per m ton H_2SO_4 is regarded as differential cost for pollution control in the case of pyrites.

It will be noted that the proportion of the credit for the steam in the case of elemental sulphur is very high (60%) and that the technico-economic disadvantages of pyrites account for about 17.5% of the total cost.

By assigning values to each item (which may be different in each country and each locality) a formula is obtained as a function of each value of raw material. Using data from Western Europe the following are obtained:

Pyrites cost = 0.367 x + 10.5 US$ per ton H_2SO_4 100%
Sulphur cost = 0.338 x + 2.9 US$ per ton H_2SO_4 100%

Since the values of the raw materials depend upon their price f.o.b., freight, conditions of loading and unloading, transport to consumer factory and other items, it is impossible to generalise on competitive prices in each case.

As an indication, it may be said that, for prices quoted for elemental sulphur of between 20 and 28 US$ per ton at the consuming factory, those for the sulphur contained in the pyrite, after allowing for the value of the by-products, vary between 1 and 5 US$ per ton.

Our conclusion is that if the value of the metal part of the pyrites makes it possible to value the sulphur content at prices lower than US$5 per ton at consumer factory, pyrite is a raw material which can compete with the present quotation for elemental sulphur.

In order to understand the economic viability of this possibility, Table 2 was drawn up on the following bases:

- Two types of pyrites are distinguished: the crude Rio Tinto and Tharsis type and the more universal flotation type.

- The metal content was assessed at between a minimum level of LME prices (Cu = £400 per m ton, Zn = £125 per m ton, Pb = £100 per m ton and Au = US$30 per ounce) and a maximum (Cu = £450 per m ton, Zn = £150 per m ton, Pb = £100 per m ton and Au = US$60 per ounce). A forecast was made of the most probable future price.

- For the sulphur content, the value was determined between a minimum of zero to a value based on equivalence with a raw sulphur cost, as previously established.

- In order to take into account the possible variations in quoted prices, recovery of the various metals, losses, buying-and-selling price bases ... etc., two columns have been calculated, one at 100% of the values and the other at 75% of the same.

It is clear from Table 2 that any process which can prove its technical and economic practicability with total costs between US$16.5 per ton treated floated pyrites and US$7.2 per ton treated floated pyrites (in the most likely cases) can produce pyrites as raw material for the production of sulphuric acid which is fully capable of competing with elemental sulphur.

In recent years a great many researchers and centres all over the world have been working along these lines,

resulting in processes which have the following two objectives:

- Maximum utilisation of the metals contained in the original mineral

- Obtaining pyrites competitive for the production of sulphuric acid

5. Generally speaking, two processes have been used for the integral recovery of the sulphur and metals contained in pyrites: those which separate the operations of pre-roasting of the ore from the later stage of metal solubilisation, and those which begin with the separation of the metals in recoverable form and finish with the recovery of the sulphur either by roasting or by producing elemental sulphur.

Although it is impossible to mention all the processes used or suggested for these operations, it is appropriate to refer to the most important of these and to give a brief account of their advantages and/or limitations in order to recommend a definite field of use.

Although all pyritic ores differ in their physical (granulometry, crystalline structure) or chemical properties, roasting and smelting have developed in such a way that there are no insoluble technical problems involved in bringing the residues into the form necessary for complete metallurgical treatment. One of the most complicated problems, that of the Iberian pyrites with their content of arsenic and other impurities, was investigated between 1950 and 1965 by American, Swedish, German and Spanish research workers, resulting in processes now in normal use, which enable them to be treated by roasting in fluidised-bed furnaces*.

DKH Process Well-known from the Henderson developments. Pyrite ashes are treated by chloride roasting with sodium chloride and subsequent acid leaching. It offers strict specifications with regard to granulometry, chemical analysis and minimum content of non-ferrous metals. The end product (iron ore as "purple ore") is not perfectly suitable for modern iron and steel making.

There are three plants in operation (Duisburg, Barreiro and Bilbao). The process is still profitable in existing plants under firm conditions of raw materials and LME prices.

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* "Spanish pyrites as raw material" - C. Mingarro and A. de Diego, "Metal" p.12-34, Madrid 1969.

Kowa-Seiko Process This was developed for treatment of the ashes of Japanese pyrites. The metals are dissolved by chloridisation with calcium chloride and volatilisation. The end products are acceptable for iron and steel making. There are various limitations in the chemical analyses of the raw materials and also in the maximum contents of non-ferrous metals.

There are three plants operating in Japan and another is being built in Canada.

The economic results are clearly positive.

Montecatini-Edison Process Italian pyrite ash is treated, resulting in a high quality iron ore agglomerate.

Its suitability for chloride volatilisation with gas in a fluid bed enables the non-ferrous metals to be recovered with considerable operating flexibility.

There is one plant in Fallonica (Italy) showing very good economic results.

LDK Process Developed by DKH and Lurgi in Germany. Employs chloride volatilisation of the metals with chlorine gas in a fixed-bed furnace. Has limits in the chemical specification of raw materials.

There is a semi-industrial plant at Duisburg (W. Germany). Its economies have not yet been fully proved for the future.

CEEI Process Follows the line of chloride volatilisation with hydrochloric acid in a fluidised bed.

There is a semi-industrial plant at Lyons (France) for the purpose of investigating its possibilities as a process on a competitive scale.

Piritas Espanolas PE Processes They comprise a very wide range of possibilities, both from pyrites and from their residues from roasting, including the hydrometallurgy of the solutions obtained, purification of gases, equipment to be used, etc.

There are industrial plants for some stages of the processes (recovery of zinc by ion exchange at Barreiro) and semi-industrial installations of other stages or fundamental parts of the integral process planned by PE: controlled roasting, oxidative leaching and hydrometallurgy of the acid solutions.

Outokumpu Process Part of Finnish flotation pyrites which is dissociated at high temperatures in a "flash" roaster recovering elemental sulphur and obtaining

pyrrhotite (magnetic pyrites) which are treated by roasting in a fluidised bed. The residues can be processed by other systems.

There is one plant in Finland. A similar technology has been applied with great success to the smelting of copper ores in other countries.

Bacteriological Processes These are based on the dissolution of the metals in an acid medium by specific bacteria.

It has not yet been applied on a large scale to non-ferrous metallurgy although the possibilities are being investigated.

Sherrit-Gordon Process The pyrites are thermally decomposed in order to recover the elemental sulphur, with subsequent oxidation in aqueous medium of the pyrrhotite and recovery of the dissolved metals by hydrometallurgy.

There are no plants on an industrial scale.

Boliden Process Employs chloride volatilisation of the ashes of pyrites on exit from the primary roasting with the advantage of utilisation of the available heat.

This process is at a development stage and there are no plants on an industrial scale.

6. Spanish programme for the integrated utilisation of Pyrites

In view of the experience gained over many years in the treatment of Spanish pyrites and the future plans of Union Explosivos Rio Tinto (ERT), a development plan has been drawn up for the processes which are specifically capable of solving the future problems of Spanish pyritic ores. In order to do this, consideration has been given to the factors of ore production (ERT can produce between one and two million metric tons of pyrites in their present mines), of the chemical industry (in 1973 ERT's consolidated production will be about 1.2 million metric tons of H_2SO_4), of Spanish iron and steel making (which will import 10 million metric tons of iron ore in 1972), of the country's non-ferrous-metal industry (ERT are producing 35,000 metric tons of primary copper and over 55,000 metric tons of electrolytic copper).

The programme follows two independent but closely co-ordinated lines of action for which simultaneous operation seems essential:

- The establishment of a factory for the processing of residues of roasted pyrites and capable of

absorbing all the ash produced between 1972 and 1982 in Spain and in the area of economic freight charges.

- The development of a process for the integrated treatment of Spanish pyrites, from mining to final metallurgy, taking into account the trends of the next 10-20 years.

Treating the Ash

In order to carry out this plan, a new company, Aprovechamiento Integral de Piritas S.A. (AIPSA), was formed. Union Explosivos Rio Tinto, the Tharsis Sulphur and Copper Company and Metalquimica del Nervion are partners in this venture. The latter at present operates a plant taking 580,000 metric tons of ash per annum at Bilbao.

AIPSA has sponsored and, when necessary, financed the investigation of the development needed to adapt the processes recently developed for the chloride volatilisation of non-ferrous metals of Spanish ash. Montecatini-Edison, LDK, CEEI and Kowa-Seiko in particular have been working on the processes.

At the moment, plans have been completed for a plant at Huelva (Spain) with a capacity of 1,000,000 metric tons per annum. It can be expanded in successive stages and constructed in 24 months.

As this project affects other Spanish industries, contact is maintained with the Spanish Government, in order to decide the final conditions under which AIPSA will carry out the project, which is of such fundamental importance in maintaining the continued growth of the Spanish mining industry.

According to present forecasts, in 1974 2,300,000 metric tons of pyrites will be consumed in Spain, and will produce about 1,610,000 metric tons of ash. The characteristics of this ash differs very much in granulometry, impurities and metal content, since there are many old and new plants in existence for roasting Spanish pyrites. It is hoped to rationalise the distribution of this ash between the Northern plant (Bilbao) and the Southern (Huelva). In order to do this, the AIPSA plant will have to be able to handle, separately or together, the ash with copper, lead and zinc contents, as well as other impurities such as those arising from the new processes which favour prior separation of the greater part of the metals by hydrometallurgical processes. This difficulty has been solved in the AIPSA project, since in the present chloride volatilisation processes, the variable manufacturing costs are very high (for example,

consumption of the chloridising agent Cl_2) and compensate almost entirely for the lower returns from sale of the non-ferrous metals.

In all the cases studied, AIPSA will be able to apply a price for pyrite ashes which will satisfy the basic principles set out in Section 4. That is to say, the cost of the sulphur contained in the pyrite, after credit for its ashes, will make the sulphuric acid produced competitive with that obtained from elemental sulphur at prices quoted at the factory between US$ 20 and 28 per ton.

Integrated Processing of Spanish Pyrites

As a result of previous studies, ERT developed a technique for separating the non-ferrous metals from their pyrites by differential and total flotation.

In order to complete these studies, they employed the services of the Empresa Espanola de Investigacion y Desarollo, S.A. (ESPINDESA) of which ERT is the principal shareholder. The hydrometallurgical process planned for this work will take place in the following stages:

- Total flotation of the metallic sulphides, obtaining a concentrate of copper, lead and zinc and also pyrites with a high content of sulphur.

- Solubilisation of the metals of the total concentrate.

- Recovery of the copper by extraction with organic solvents and direct electrolysis of the solution to produce cathodic copper.

- Recovery of the zinc by electrolysis of the previously purified solution in a sulphuric acid medium.

- Recovery (if desired) of the lead by extraction with amines or precipitation as carbonate.

- Recovery of the precious metals.

- The complementary recovery of cobalt and cadmium.

In carrying out the various stages of the process, the company collaborated with various Spanish and foreign research laboratories (ADARO, AUXINI-Piritas Espanolas, CENIM, Warren Springs, etc.).

The systematic investigation of the first phase (total flotation) showed results of concentration between 5:1 and 8:1 (giving a concentrate between 30 and 40% of metallic content) with recovery of metals of the order of 85-95% for Cu and Zn, and 65-75% for Pb.

A large part of the research was directed towards solubilization of the total concentrate. Various alternative studies were made, all in parallel, with very encouraging results which may well be of assistance in designing a pilot plant and making preliminary studies of industrial viability in the near future.

The stages of final metal recovery are fully established and finalised with tests on a small pilot plant. The techniques employed are of industrial use, while the recovery of copper using the range of LIX reagents of General Mills (U.S.A.) has some aspects of technical novelty. At the present time, a study is being made for the optimisation of these processes in the light of the results obtained in the previous stage of solubilisation.

The fundamental technico-economic principles of the process, which encouraged its development, may be summarised as follows:

- Use of known techniques which could be adapted to the special needs of Spanish pyrites quickly and with only moderate risks.

- Maximum use of "clean" techniques, i.e. with reduced effects in the operations of pollution control. The hydrometallurgy chosen makes it possible to ensure a high quality of operation with regard to the environment.

- Maximum recuperation of the metal content and achieving a degree of purity obviating "stages in cascade" which would endanger the overall profitability of the process. These products are: pyrite concentrates of great fineness, electrolytic copper, electrolytic zinc, metallic or easily purifiable lead, gold and silver as fusible concentrates.

- "Flexible" economies in the sense of being adaptable to ores of very different characteristics and the use of modular production units; flotation cells, intermittently-running reactor, electrolytic cells.

- Obtaining "residues" which can be reprocessed separately, such as cobalt and cadmium.

The object of the process is to make profitable the investment required to achieve integrated reduction of the pyrite ore and, by obtaining a concentrate of flotation pyrite, to provide the chemical industry with a raw material clearly competitive with elemental sulphur.

In order to evaluate this assertion it must be borne in mind that the joint operation of the plants based on the process being studied at present, ERT - ESPINDESA and the chloride volatilisation plant of AIPSA, working wholly or partially with ashes of flotation pyrite and obtaining a "pellet" of iron ore of high siderurgical quality, would constitute an integrated industrial complex with good-medium-and-long term prospects of profitability.

In view of the of the great importance of this project to Spain, considerable progress has been made towards full agreement between the mining companies and the Government. This will establish definitive terms and conditions on which the project will operate.

TABLE 1

Structure of costs of production of sulphuric acid from pyrites and elemental sulphur as raw materials

Basis: Investments on 1972 information - Europe

Capacity: 1000 tpd

Item	% Total Production Cost		Remarks
	Pyrites	Sulphurs	
A- Raw materials (nett)	x	y	0.367 tons of sulphur contained in pyrites and 0.338 tons of elemental sulphur per ton of H_2SO_4 100% are consumed
B- By product steam (Credit)	(17.5)	(60)	
C- Services: (including power, process-water, refrigeration etc.)	20.5	32	
D- Production costs (including labour, supervision, maintenance, circulating capital and depreciation)	79.5	128	
E- Differential costs (including differences of cost of capital invested in plant or plants, pollution etc.)	17.5	-	
TOTAL	100	100	

TABLE 2

Intrinsic value of one ton of Spanish Pyrites under different conditions

Type of Pyrites	Conditions of market LME & sulphur	100% of the LME value for metals (US$ per ton)	75% of LME value for metals (US$ per ton)
Crude Pyrite: S= 48% Cu= 0,8-1,2% Pb= 0,5-1,5% Zn= 1,5-2,5% An= 1 g/t Ag= 30 g/t	Minima	18.75	13.6
	Most probable	21.95	16.5
	Maxima	31,65	23.7
Floated Pyrite: S= 48% Cu= 0.3% Pb= 0.3% Zn= 0.4% An= 1 g/t Ag= 30 g/t	Minima	7.52	5.6
	Most probable	9.57	7.2
	Maxima	11.57	8.6

Note: The value of other minor components (Co, Cd, Se) is not included.