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NEW PROCESS ROUTES FOR THE RECOVERY OF MAGNESITE RUN-OF-MINE (R. O. M.) FINES (MAGFINES)

by [1]

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ABSTRACT

The establishment of new procedures for the recovery of magnesite R.O.M. fines (-12mm) in Grecian Magnesite's (GM) mines, was researched through a Brite EuRam project labelled "MAGFINES". In the first stages of the program extensive work on raw material appraisal and sample preparation and characterisation was carried out in collaboration with the Institute of Geology and Mineral Exploration (IGME). Detailed chemical and mineralogical analyses revealed main constituents and beneficiation properties. These data were used by Control International SA (CI) to develop a new ore model to be used for process simulation. Process testing performed by GM and IGME comprised a large number of laboratory, pilot and industrial scale tests with various beneficiation techniques. Furthermore GM developed, commissioned and tested a new prototype optical Sorter for the +6mm material. Based on testwork results the partners selected a generic flowsheet employing pre-separation of fines in dry state using magnetic or non-magnetic drums, follo wed by scrubbing and wet sieving for the preparation of the material, TRIFLO heavy media separation and then optical sorting for the +6mm fraction and magnetic separation for the 2-6mm fraction. Relevant unit operations models were deveioped by CI and were calibrated using the experimental data from process testing. The USIM PAC process simulator was used for the optimisation of the selected flowsheet by evaluating a great number of alternative configurations. Finally, tentative applications and market data for magnesite grades derived from the selected flo wsheet were investigated.

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1. INTRODUCTION

The project labelled "Magfines" was implemented within the framework of Brite Euram II Program unter Contract No BRE2-CT92-0388. It concerns new process routes for the recovery of magnesite Run-Of-Mine (ROM) fines, based on the mines and stockpiles of Grecian Magnesite **SA** (GM). Fine ROM material refers to the O-12mm size fraction which can not be processed with currently available techniques and is stockpiled. The problem is substantial since the 0-12mm material represents about 1/3 of the total ROM material in GM's mines and contains about 30% of $MgCO_3$.

The main objective of the program was to develop a new process to recover the wasted magnesite fines, thus slowing down the depletion of natural mineral wealth, increasing rnagnesite production capacity at a low cost and reducing the waste disposal area requirements.

Except GM, the other partners in the project were the Institute of Geology and Mineral Exploration (IGME) of Greece, Control International SA (Cl) of France and, until 19.2.95, Cryogenic Ltd of the UK (CL).

The research work comprised the following:

- Material appraisal, sample preparation and characterisation. The 0-12mm material and its béneficiation properties were fully defined and a new ore model was developed.
- Development of new beneficiation techniques. GM developed commissioned and tested a new prototype optical ore sorter. Development of a Cryogenic High Intensity High Gradient Magnetic Separator (CHIGS) by CL was not successful.
- Adaptation testing and evaluation of existing beneficiation techniques, most of them for the first time on magnesite ore. These included, pre-separation of fines by magnetic or non-magnetic drums/rolls, TRIFLO heavy media separation, Rare Earth Roll Magnetic Separation etc.
- Selection and testing of a generic flowsheet in its entirety.
- Modelling of unit operations and optimisation of the generic flowsheet, using simulation techniques. Mathematical and computer models for the new separation techniques were developed and calibrated using actual test data. Optimisation was performed through simulation of alternative flowsheet configurations
- Evaluation of final products and investigation of tentative applications and market data.

2. TECHNICAL DESCRIPTION AND RESULTS

An **overview of the** technical work is presented in the following sections:

2.1. RAW **MATERIAL APPRAISAL**

The sampling campaign, a complicated and time-consuming task, which generated bulk sample(s) for testwork, has concentrated on the various run-of-mine (ROM) fine stockpiles from different time-periods of dumping and on currently generated ROM fines from various pits. The main recommendation from this step was that future work should mostly concentrate on the current production ROM fines.

2.2. **CHEMICAL ASSAYS** AND PHYSICAL Properties

A large number of chemical assays was performed. Classic chemical methods, XRF analysis etc. were used and results compared, with no major differences noted. Size distributions were obtained by wet screening and chemical analyses were carried out within each size range. Mineralization of each material and of each size range was measured, both by meticulous hand-sorting and by measuring CO_2 contents. Humidity and apparent specific weight measurements were also carried out. Throughout this analytical work, comparisons were made with (older and current) industrial-scale analyses that GM **uses for production purposes.** The main findings were :

- Stockpiled and current ROM production of 0-12 ROM are very similar
- 0-12mm ROM is around 1/3 of total ROM feed and consists of approx. 60% of +1mm or 30'?40 of +5mm.
- The "magnesite" content **of** +2mm is 20-40% by weight, with its' quality ($S10_2$ 'Io) deteriorating with size.
- CO_2 could be used as an accurate surrogate measure of $MgCO_3$ content for modelling purposes, at least of RONI and pre-concentrates.
- Humidity (≈10%) due to hydrous phases, will not allow easy dry screening and water non-availability will be a problem for wet screening, e.g. at 5mm.
- As was also confirmed later, the possibility of having an initial stage of a large (magnetic or non-magnetic) drum to separate fines, instead of through the use of screens, was proven attractive.

2.3. MINERALOGICAL STUDIES

Various mineralogical analyses were carried out on 0-12mm magnesite ROM material, by optical microscopy, by thermoanalysis and by X-ray diffraction.

According to the results of this study, the fragments of 0-12mm raw material consist of magnesite (≈20 -25%, mean value i.e. similar to that obtained by chemical analysis] as well as gangue minerals. The last are mainly serpentine, but also in smaller proportions, pyroxene, quartz, dolomite, calcite, talc, chlorite and in minor amounts olivine, chromite, magnesite, iron-hydroxides and phyllosilicates.

Magnesite is of cryptocrystalline type, very pure and occurs as liberated fragments in all examined samples. These fragments may consist only of magnesite, but may also be composite, in addition consisting largely of quartz, iron-hydroxides, serpentine, talc and calcite. However, it must be noted that most of the fragments are monomineralic, namely magnesite. The composite fragments is an important factor for the selection of processing methods and affects the qualitative and quantitative character of the final products. Complete liberation and removal seems extremely difficult. Serpentine (iron hydroxides) could prove "useful" for magnetic sorting.

These results were later used, i.a., in constructing an ore model.

2.4. BULK SAMPLE PREPARATION

The main objective was to collect quantities of approx. 20 tons from the currently produced 0-12mm and another approx. 20 tons from the stockpiles. Two different samples were taken from the stockpiles. By taking samples at fixed time periods, another two samples were created from the current production. It was noted, however, that ore characteristics were such that one sample from the current production, an aggregate of the initial two, was enough and the same was found to be true of the stockpiled material.

Two final samples, one current and one from stockpiles, were submitted for beneficiation studies.

2.5. STUDY ON THE BENEFICIATION PROPERTIES

Pilot plant scrubbing and wet sieving tests on the bulk samples were effected, with emphasis on the current 0-12mm material. The products were of two kinds : large for further treatment and small for additional laboratory investigation. The results confirmed the conclusions of the laboratory classification, except that the material submitted to scrubbing and sieving seems to be slightly finer, due to its' friable nature.

Hand-sorting was carried out on different size fractions, all +5mm, with approx. **40°/0** of the material being separated as a potentially commercial grade, as it consisted of mostly (92-95%) magnesite. Overall recovery of magnesite was approx. 75% and the main impurity ($Si0_2$) varied from 1.2 to 3%, i.e. the product was rather pure.

Furthermore, different types of laboratory magnetic separation were effected. One, utilising rare-earth magnetic separation technology, was performed in conjunction with tests on the early optical prototype. Another, using a Frantz isodynamic Separator (FIS) proved the importance of magnetic separation for the material in question as (a) the magnesite content about doubled (to 55-6 0%) in the "non-magnetic" product compared with the feed, with a recovery of around 75% and (b) 90% of total Fe_20_3 was recovered in the "magnetic" product.

2.6. SORTER DEVELOPMENT

Development of a new Sorter proceeded quite satisfactorily. This machine is using Reticon Camera technology for particle recognition rather that lasers as in existing models which are processing +12mm materials. Construction, debugging, commissioning and testing of the machine were accomplished, while the main "pilot" test result of 6.3% black in accepts and 16.7% white in rejects was considered quite good. The results of a large-scale test were as follows :

Feed rate :	0.76 t/h
Magnesite in the feed, weight :	43.20/0
Accepts, weight :	36.9%
Content of accepts :	10.9% black, 89.1% white
Rejects, weight :	63.1%
Content of rejects:	83.7% black, 16.3% white

Installing additional cameras is expected to improve tonnage almost proportionally to the number of cameras that will be used (up to four per machine). It should be also noted that the performance, i.e. capacity etc., of the sorter will be further enhanced as material containing an ore-to-waste ratio that is away from the 1 - to -1 range is fed to the machine (e.g. 25°A ore : 75% waste).

2.7. CHIGS DEVELOPMENT

The Cryogenic High Intensity High Gradient Separator was intended to be an open gradient system treating material in dry state and thus contributing in minimizing the quantity of material that would have to be wet processed. Some preliminary laboratory-scale tests were made on various samples, followed by efforts on detailed engineering of the prototype separator, on testing of the refrigeration system and on *starting* of manufacture of the CHIGS machine. TestWork on the demonstrator magnet coil built with NbSn superconducting material and on the Gifford-McMahon type refrigerator has continued together with other engineering and theoretical work.

However, serious problems with the design of the separator and with the test coil, have resulted in discontinuation of the CHIGS development.

The project concentrated, instead, on alternative magnetic separator technologies, notably rare-earth roll separators.

2.8. PROCESS TESTING

Further to testing on the sorter described above, there was work on

a. Pilot plant scale scrubbing and sieving (Pre-treatment),
b. Crossbelt magnetic separation,
c. Wet high intensity magnetic separation (whims),
d. Rare-earth magnetic separation,
e. Magnetic drums/rolls for fines separation,
f. Non-magnetic drums for fines separation,
g. Laboratory and pilot heavy media cone and cyclone,
h. Pilot and industrial scale testing on TRIFLO heavy media separation,

This work was classified in three categories :

First, material pre-treatment, magnetic separation and heavy media separation as per items a, b, c, d and g above. This first category comprised (a) scrubbing and sieving of ROM material in pilot plant equipment to produce samples for further treatment and work on various types of magnetic separation of the run-of-mine 0-12mm material and on heavy media separation products and (b) rare-earth magnetic separation of the products of the sorter.

The second category as per items e and f consisted of developing and testing magnetic and non-magnetic pulleys for fines removal. A pilot scale non-magnetic drum separator was constructed by GM and was tested to prove the feasibility of the idea. Results were promising and indicated that a substantial amount of the fines could be separated in dry state. Further tests were decided to be run during the testwork for verification of selected flowsheet. In parallel, tests were run in collaboration with major magnetic separator manufacturers on the idea to use magnetic drum or roll separators for the same job. Although results with roll separators were better, drum separators were considered more practical in the tough conditions of ROM material processing.

Finally, the third category comprised pilot testing on TRIFLO together with rare-earth magnetic separation tests on the TRIFLO products. An outside consultant was utilised on pilot-plant TRIFLO testwork, and also submitted a technical report on applicability of the TRIFLO method on magnesite together with some pre-feasibility data. Results obtained from the pilot plant TRIFLO tests are considered indicative, since the specific installation had technical limitations and it was not possible to perform continuous tests with substantial quantities of feed material. Therefore, testing in an industrial unit was decided to be included in the testwork for verification of selected flowsheet.

Magnetic separation on the TRIFLO products proved very efficient. Final products of acceptable quality were derived. It is therefore anticipated that the combination of TRIFLO and RER magnetic separators would be successful in producing commercial grades of magnesite.

2.9. INTERPRETATION OF THE RESULTS AND PROCESS SELECTION

Evaluation data of results and deliverables from material characterisation and process testing were used in order to set up a flexible generic flowsheet for the 0-12mm ROM material.

The conclusions from process testing evacuation can be summarised as follows :

- Scrubbing and wet sieving are effective in removing the finest fractions of the material. However, due to the high percentage of fines and friable constituents, water consumption is large and a considerable amount of mud is created.
- A magnetic or non-magnetic drum separator can be used for the removal of a percentage of the fine fractions in dry state, thus alleviating the water consumption and mud production problems.
- Heavy Media Separation proved to be effective and flexible in treating a wide range of grain sizes. Essential prerequisites for the successful use of any HMS technique are: a) the thorough cleaning of the material at a scrubbing stage and (b) accurate control of puip stability.

- The Sorter prototype developed and tested proved to be very effective in processing of the 5-12mm material. It is estimated that in combination with an HMS stage it could yield final magnesite products of commercial grade.
- Magnetic separation using Rare Earth Roll (RER) separators is suitable for the beneficiation of the 0-12mm material, due to the high content in ferrous serpentine group material. More specifically, tests with material treated by HMS indicated that a combination of HMS and magnetic separation can be effectively used for yielding of commercial grade products in the 2-6mm size fraction.

Based on the above points, the partners finalised a generic flowsheet for the processing of the 0-12mm ROM material. The main thinking was as follows :

- A cut-off point at 2mm was decided for the removal of the fines.
- A two-stage fines removal was decided. The first stage should be in dry state using a magnetic or non-magnetic drum separator cutting at 2mm. The second stage should bean intensive scrubbing operation with wet screening at 2mm afterwards.
- The TRIFLO would be the main processing technique for the pre-concentration of the magnesite ore, since it can be applied to a wide size fraction range. A second cleaning TRIFLO stage could follow to obtain higher grades.
- Optical sorting will be used for processing the +6mm TRIFLO preconcentrate in order to have a final product.
- The 2-6mm fraction will be treated by RER magnetic separators.

The resulting generic flowsheet is presented in Figure 1. Several alternative configurations from this can be derived. Points of differentiation are in the use of:

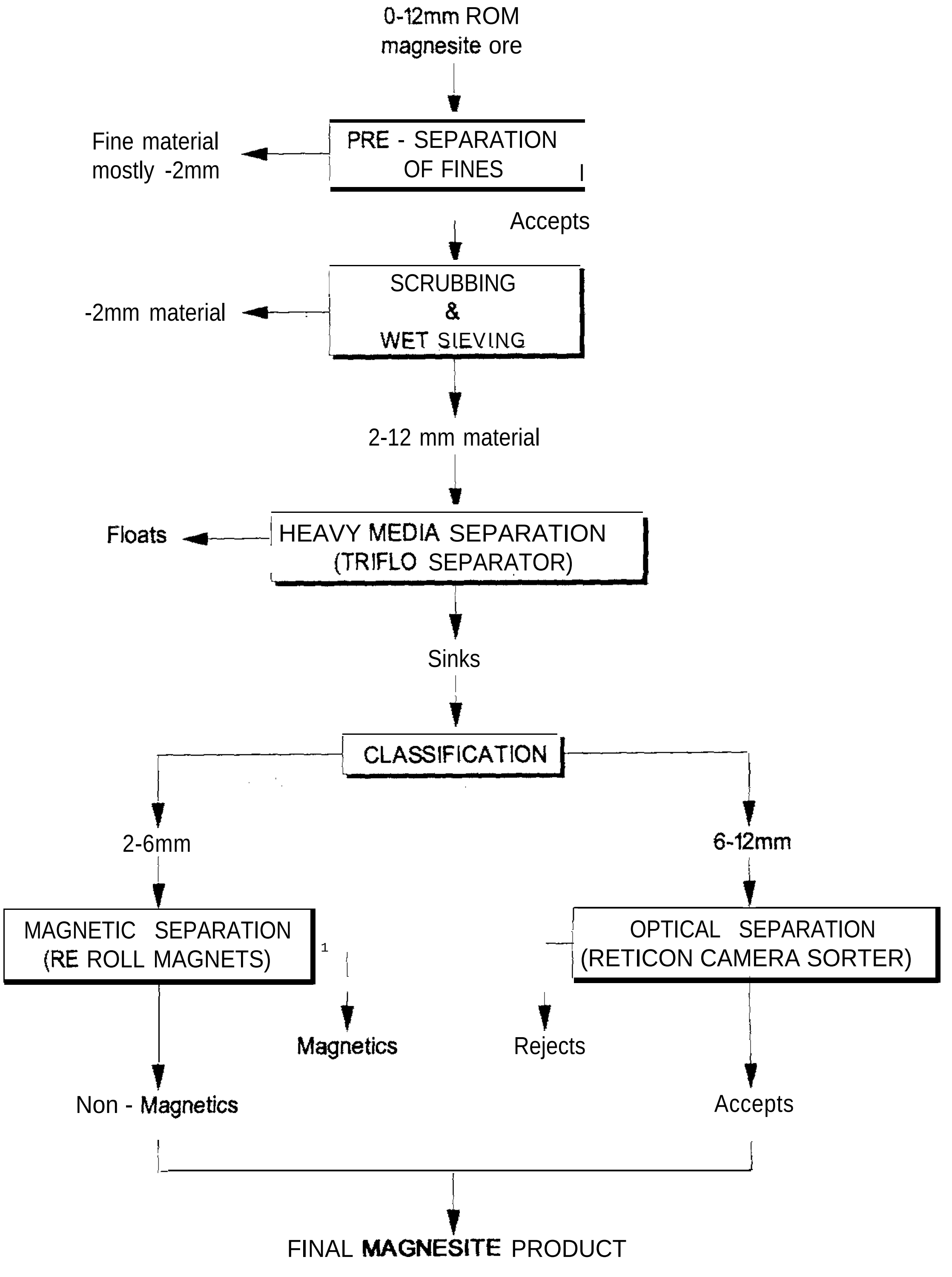
. non-magnetic or magnetic drum separator in the pre-separation of fines stage,
. single pass or double pass TRIFLO,
. dried feed to the RER or wet as derived from the HMS stage.

A substantial number of alternative configurations was derived applying these multiple choices., The testwork for the verification of the selected process aimed at providing the data needed to simulate these alternatives in order to evaluate the optimum configuration.

2.10. TESTWORK FOR VERIFICATION OF SELECTED FLOWSHEET

In order to investigate the applicability of the selected generic flowsheet a bulk testwork was planned and executed, comprising all the beneficiation techniques previously tested

FIGURE 1: Generic Flowsheet for processing of the 0-12mm ROM material.



separately. Furthermore, the data of this testwork were essential for the calibration of the unit operation models used for the simulation of the selected flowsheet.

A quantity of 100 tons of 0-12mm ROM material was taken from the current production. It was treated in an industrial TRIFLO unit which comprised also a scrubbing and wet sieving stage for the preparation of the feed. The sinks product was classified in two fractions namely 2-6 mm and 6-12mm. The former was processed by RER magnetic separators and the latter by the RCS machine.

Separately a quantity of 250 kg of ROM material was passed through the pilot non-magnetic drum separator to investigate separation of fines at 2mm.

The Non-Magnetic Drum testwork indicated that fines removal at 2mm is feasible with about 50'% of the -2mm material contained in the feed rejected. This is comparable to results obtained with magnetic drum separators. The non-magnetic drum separator is considered as a simpler and cheaper machine to remove part of the fines abte to withstand the difficult conditions of ROM processing.

For the TRIFLO tests an industrial installation in Greece, 500 km away from Yerakini was chosen. This installation is optimised for the treatment of other materials and this resulted in various technical problems when the magnesite ore was treated. However, results obtained ROM these single-pass tests were better than results from the pilot plant testwork.

The +6mm sinks product from the TRIFLO was treated by the sorter prototype giving satisfactory results. The -6mm was treated by RER separators. Two different cases were studied i.e. one with dry feed and one with wet feed (7°/0 humidity). Tests indicated that wet feed reduces the performance of magnetic separation by about 10% regarding machine capacity, as well as silica content and weight recovery of the non-magnetic product.

2.11. OPTIMISATION OF SELECTED FLOWSHEET

Model-based, steady-state optimisation was used as the most powerful approach to maximise the efficiency at the design stage. An ore model was developed as a format for representing processed material. Mathematical models were selected, adapted or developed for several unit operations which were considered for the final flowsheet. All unit operations were then calibrated and evaluated with actual (experimental) data. Model parameters were determined from extensive laboratory, pilot plant and industrial testing. Lastly, the process flowsheet was defined, simulated and optimised. The USIM

PAC package was used for the simulation. A number of alternative flowsheets and configurations were defined. Evaluation and comparison of alternatives made it possible to optimise equipment selection, operating conditions and process flowsheet for different commercial end products.

More specifically, the ore model was based on a methodology to convert chemical composition into mineral composition. The ore composition, expressed in mineral classes, was calculated from the chemical assays through a set of formulas. Thus, size-by-size mineral composition of a given sample is derived by carrying out chemical assays only. The principle behind the ore model and the respective conversion formulas are given in Figure 2.

As for simulation models, two were developed especially for this project "from scratch", one for the cryogenic high intensity high gradient magnetic separator and another for the reticon camera sorter. The latter was extensively used in process selection and optimisation. In addition to these two models, a selection of other standard ones has been made while still others were adapted from standard models e.g. TRIFLO from dense medium cyclones.

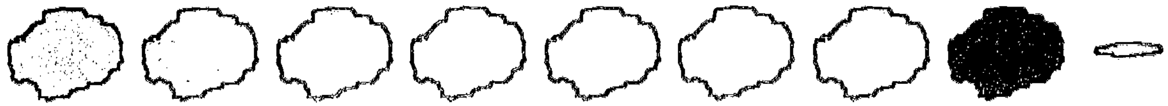
The calibration of the models was based on experimental data available from laboratory, pilot or industrial operation of the unit of equipment considered. Such data consist of size, chemical and mineralogical analysis of samples taken from the feed and output(s) of the unit while operating. Geometry and operating conditions of the units and physical properties of minerals were used as inputs to USIM PAC. The values of the unknown adjustment parameters were back-calculated on several eligible unit operations: TRIFLO, RCS, CHIGS, Dense medium cyclones and cones, RER, magnetic drum, non magnetic drum.

The final step was flowsheet optimisation through assessment of several alternative configurations of the generic flowsheet. In total ten alternative configurations were simulated using the USIM PAC software. The outcome of the simulation was a full description of all material streams for each alternative flowsheet configuration. Available data included, solids and water flowrates, size distributions and mineral distributions that were converted to chemical assays using the ore model. These data were used in the final evaluation phase in conjunction with experimental data and market data for the selection of the most suitable production scheme.

MAGFINES - definition of mineral classes

MAIN MINERALS	SERPENTINE CHLORITE	MAGNESITE		QUARTZ	CALCITE DOLOMITE	TALC	PYROXENES	IRON OXYDES	
Xmy diffraction (as an indication of pure elements)	40 %	30 %		10 %	9 %	8 %	3 %	0%	total 100 %

COLOR (typical)



	altered (clear)	composite (silica, serpentine, iron)	pure					liberated in small fractions only (goethite, magnetite)	
MINERAL CLASSES	SERPENTINE	COMPOSITE MAGNESITE	MAGNESITE	SILICA	COMPOSITE MAGNESITE		SERPENTINE		
Calculated (see conversion below)	73.6 %	6.7 %	14.8%	4.9 %					

Conversion method : BETTER KNOWLEDGE OF TYPICAL MINERAL COMPOSITION/LIBERATION
FEWER ASSUMPTIONS ON RECOVERIES TO MINERAL CLASSES

ASSAYS	MgO	CO2	SiO2	CaO	Fe2O3	MgCO3
	27 %	15.5%	34.5 %	3 %	9.3 %	20.16%

All CaO is associated with CO_2 in the form of $CaCO_3$
80% of total $CaCO_3$ is in the form of dolomite
All CO_2 not in $CaCO_3$ is in the form of $MgCO_3$

Typical grade of pure magnesite fragments is 95% $MgCO_3$, 2.5% SiO_2

Typical grade of composite magnesite fragments is 75% $MgCO_3$, 15% SiO_2. 20% of total $MgCO_3$ is in the form of composite magnesite fragments

Typical grade of silica fragments is 20% $MgCO_3$, 70% SiO_2. 10% of total SiO_2 is in the form of silica fragments

Typical grade of serpentine fragments is 7% $MgCO_3$, 50% SiO_2

AN ITERATIVE PROCEDURE IS USED TO SOLVE THE SYSTEM

Figure 2 : Definition of Ore Model

2.12. TESTING AND EVALUATION OF FINAL PRODUCTS

This comprised the following :

a) Evaluation of the results of the computer simulations, regarding the product quality derived by each alternative flowsheet configuration.

t)) Calcination tests of the products derived from testwork for verification of selected flowsheet.

c) Study of the tentative applications and market data for the selected final products.

Finally three of the ten simulated alternative flowsheet configurations were selected as satisfying the three tentative production objectives which were set :

a) Production of the best possible commercial grade with about **4%** SiO_2 content (Grade **A).**

b) Production of a low quality commercial grade with about 6-7% SiO_2 content (Grade B).

c) Production of a low non-commercial grade with iess than 85% $MgCO_3$ to be used for calcination and further beneficiation in the calcined state.

Data on the three flowsheets and related products are given in Table 1. Furthermore, the flowsheet configurations in cases (a) and (b) are shown in Fig. 3 and 4 as given in the USIM PAC simulator. Calcination tests were performed with products of the first two categories. These confirmed the simulation results and indicated that SiO_2 content is a more reliable estimator of the quality of the magnesite products under examination.

TABLE 1: Summary results from simulations

Flowsheet-#	CHARACTERISTICS	TOTAL PRODUCT		
		$MgCO_3$	SiO_2	Recovery
7	Non-Mag Drum, 1 stage TRIFLO RER wet	80,05	9,37	7,84
9	Non-Mag Drum, 2 stage TRIFLO RER wet	90,12	4,07	3,85
16	+6mm as #15 2-6mm, 1 stage TRIFLO, RER dry	85,93	6,29	7,32

Magnesite derived from the MAGFINES flowsheet can be used for the production of deadburned magnesia, caustic calcined magnesia or can be used in the raw state for certain application.

Figure 3: Flowsheet #16, production of low grade

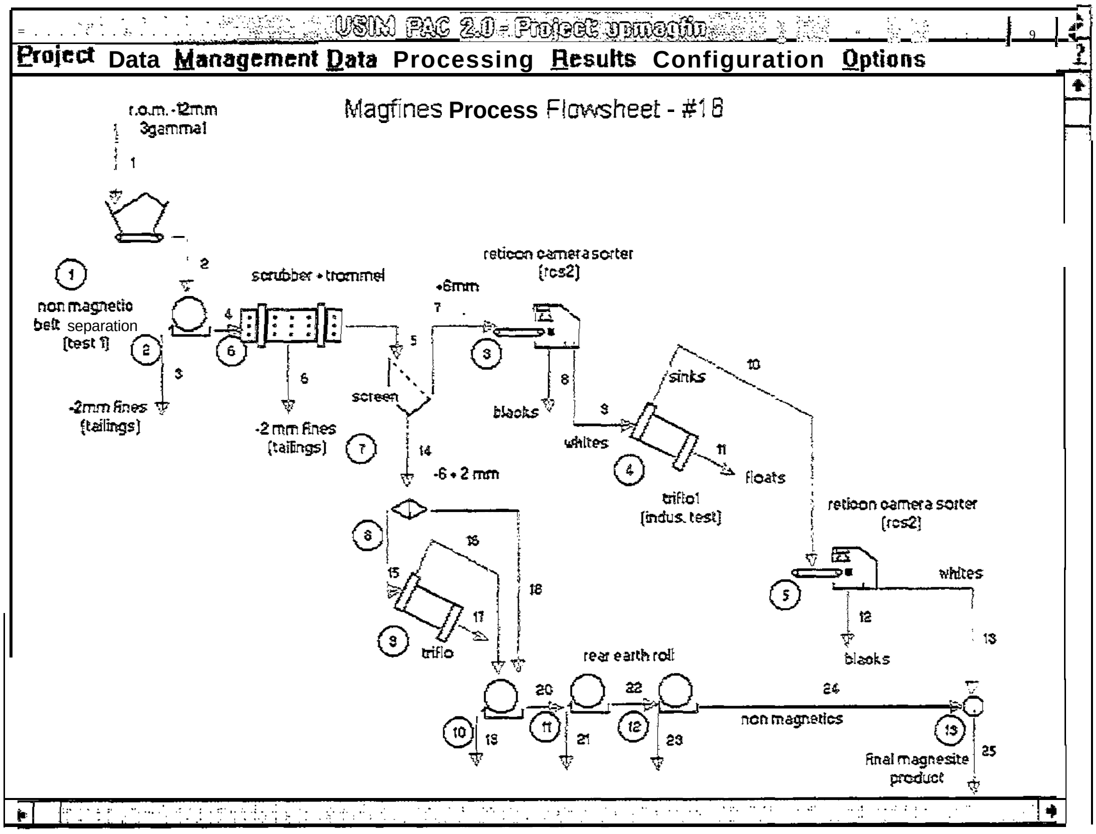
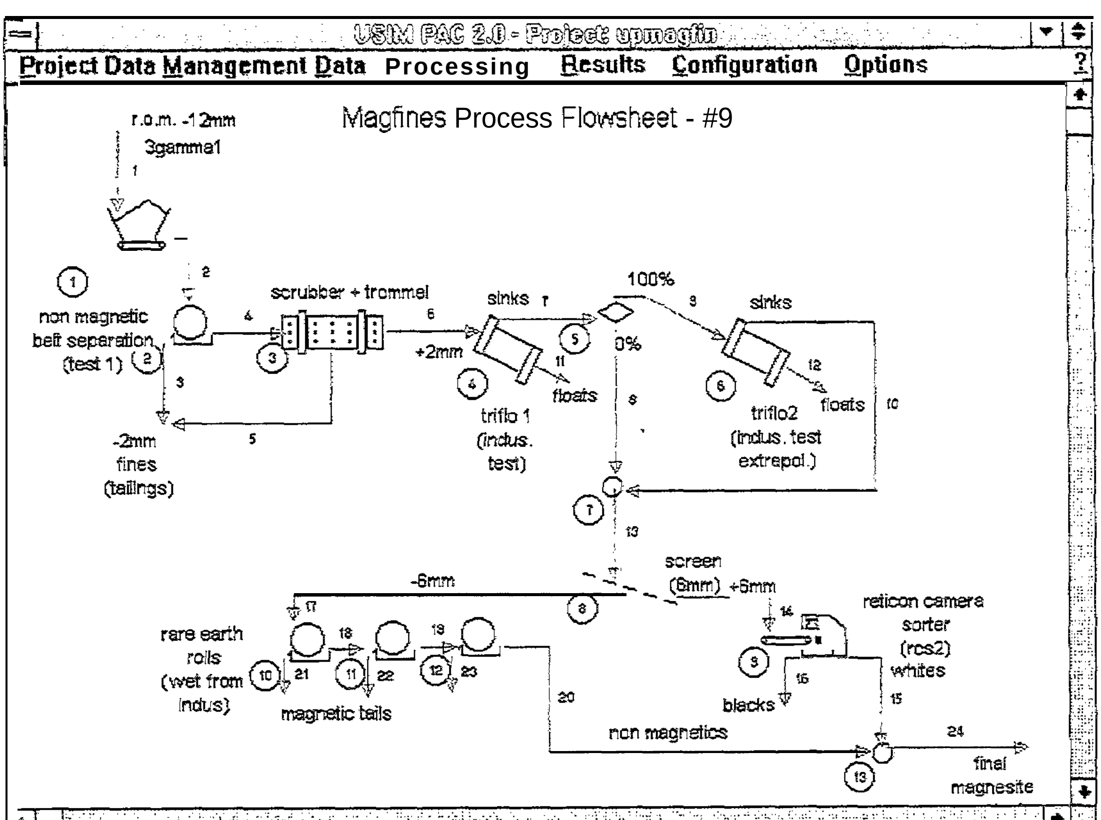


Figure 4: Flowsheet #9, production of best possible grade



Deadburned magnesite could be produced only from Grade A due to technical reasons. Products with 9-10% SO_2 and 85-87% MgO can be used for refractory monolithic and spray dried basic insulating powders. Higher grades with about 8% SiO_2 and 88-89% MgO can be used for magnesium metal production and welding fluxes formulation.

Caustic magnesia can be produced from both grades. Tentative applications are the following:

a) Sorel industrial floors, abrasives and panels, with SiO_2 content 8-12% and MgO ranging from 88 to 83% respectively.
b) Slag conditioning, where requirements are for 75-80% MgO and 12-15% SiO_2.
c) Chemical and environmental applications, where low qualities of 60-80% MgO are used for neutralisation of acid wastes and for the treatment of flue gases in oil fired power stations.
d) Agricultural applications as fertilisers and cattle feed with typical grades containing around 83% MgO and 12% SiO_2.

Finally, magnesite could be used at the raw state for fertilisers and slag conditioning and in the production of ceramic tiles.

3. CONCLUSIONS

The problem that was tackled in the framework of this project proved exciting and challenging. The very effective collaboration between GM, IGME and CI contributed to approaching an acceptable solution. Major individual conclusions are the following:

During raw material appraisal it was found that the material is very difficult to process, for three reasons: large percentage of fines, many different kinds of impurities, wetness/stickiness. The solution applied 'upstream", i.e. the pre-separation of fines by drums/rolls before scrubbing, rather than by dry screening or by washing/scrubbing the entire 0-12mm ROM material, proved simple and quite helpful. It was also established that further downstream in the flowsheet, no single method could provide the required results but a combination would be necessary. The optimal combination was determined in subsequent tasks. The work on raw material appraisal was (iteratively) interfaced with the development of an "ore model" that enables to estimate the mineralogical composition of different materials from their chemical assays which can be determined fast and accurately.

The tasks of sample preparation / characterisation and equipment development / process testing, in combination, established the basis for selecting the actual combination of methods that could lead to a commercial product. TRIFLO heavy media was shown to be a significant component, following scrubbing and sieving. Subsequently, rare earth magnetic rolls for the 2-6mm and a new reticon camera sorter for the 6-12mm material will act as final steps at the raw stage. Calcination could follow. It is a drawback that development of a cryogenic magnetic separator was not achieved, as such technology was hoped to be of considerable assistance not only in providing a very high, magnetic field and intensity but also in reducing the quantities that have to undergo wet processes such as scrubbing, wet sieving and TRIFLO heavy media with the associated problems of water requirements, mud production and considerable operating costs.

Interpretation of results/process selection and testwork for verification of selected process as well as testing and evaluation of final products, led to the conclusion that <u>many</u> combinations of methods are feasible. Several trials, physical as well as on computer, proved that three criteria should prevail: minimizing handling of fines, maximizing the quantity to be treated when the material is still at the <u>dry</u> stage and minimizing the capacity need for expensive machinery such as RCS. These were the main reasons for choosing the generic flowsheet. The above conclusions were also confirmed during the extensive testwork on verification. This helped select the final alternative flowsheets through a large number of computer simulations.

Regarding final products ●, both objectives set out were achieved, i.e. producing grades that are comparable to those marketed today and described in a general market study carried out as well as lower grades for which a special market study was also carried out in the framework of this project. Both classes of products were found to be achievable with the selected flowsheets. Preliminary work on pre-feasibility aspects led to the "suspicion" that a relatively "heavy" flowsheet is needed to produce current (higher) grades and a detailed feasibility study will be needed to confirm the viability of such a project at today's market prices that, however, are currently rising. The "lighter" flowsheet will also have to be seen against the background of lower prices that inferior grades can fetch in the market. More work is definitely needed in this area.

Some interesting "products" that came out of the research in the framework of this project can find applications in other projects as welt, such as in different industrial minerals, in recycling of products such as glass and computer scrap etc.

• new equipment developed (sorter)

" It should be mentioned at this point that the actual $MgCO_3$ content of the products could be somewhat higher than estimated by the ore model.

- new uses of existing unit operations : non-magnetic drum separator, magnetic drum separator, TRIFLO heavy media
- a magnesite ore mode{ (new)
- new phenomenological models for cryogenic and reticon-camera sorting
- adaptations / refinements of models on RER and TRIFLO

Other parts of the research, such as the mineralogical and liberation studies, the simulation methodology, the market studies etc., can be used elsewhere in similar magnesite operations.

Summarizing these conclusions, it can be said that the problem of the recovery of magnesite from run-of-mine fines came close to a solution and that, in the process, significant independently-viable hardware and software "by-products" were generated. Future work should include an economic evaluation in the form of a detailed feasibility study, a new test on the TRIFLO industrial installation, scaling-up of the sorter, search or an alternative cryogenic magnetic separator, application to other industrial minerals and different kinds of scrap etc.

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