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STRENGTHENING GOVERNMENT SUPPORT SERVICES IN NON-METALLIC MINERAL SECTOR.

TESTING OF RAW AND CALCINED MAGNESITE ORE

DP/ZIM/83/006
ZIMBABWE

Terminal Report

Prepared for the Government of Zimbabwe
by the United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

Based on the work of Jovan Vlajcic and Ivan Budimir
refractories experts

United Nations Industrial Development Organization
Vienna

This report has not been cleared with the United Nations
Industrial Development Organization, which does not,
therefore, necessarily share the views presented.

ABSTRACT

The work on the project TESTING OF RAW AND CALCINED MAGNESITE ORE (Ref. DP/ZIM/83/006) has been done during the period 25.04.1987 through 22.08.1987, a total of 17 weeks.

The objective of two experts mission was to assist Zimbabwean Govemnment, to carry out semi-industrial investigations, and to explore technical viability of a beneficiating technology, developed earlier, for reducing high lime content of Kadoma raw magnesite, enabling thus its use for the production of hifh quality basic refractories, In addition, as many relevant input data for the preparation of the feasibility study should be collected from this work, as possible.

Semi-industrial tests consisted of precalcining of different sizings of the ore, taken from regular production of Kadoma mine - at different working temperatures, and of processing of obtained calcined material by selective hydration process.

The investigations have been carried out in two steps:

- Trial tests, aimed at determination of optimal oporational conditions for the main test, and
- Main test, in the course of which about 170 t of raw magnesite have been calcined and processed.

By applying the proces of selective hydration following semi-products have been obtained (starting material = calcined magnesite had 6.23 % CaO):

Semi-product	Quantity t	Lime Content %	Lime reduction %
SP - A	22.4	3.67	- 37.4
SP - B	19.1	4.64	- 20.0
SP - C	27.4	9.16	+ 59.2

By simple additional processing (tumbling + screening) of semi-products "A", and "B", new semi-products of improved quality have been obtained:

Semi-product	Recovery %	Lime Content %	Lime Reduction %
SP - AT	20.20	3.34	43.2
SP - BT	29.45	3.46	41.2

Semi-products SP-AT, and SP-BT, according to their chemical composition, belong to the group of magnesite concentrates, which enable the production of high quality dead-burned magnesite, and basic refractory bricks.

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Semi-product "C", despite of its high lime content, represents a valuable, salable product, which is used as an additive to fertilizers, but it has many other industrial applications, as well.

The results, obtained from these semi-industrial investigations, have confirmed, that the selective hydration process can successfully used for upgrading of Kadoma raw magnesite, fully justifying the test work done, also.

It has been recommanded:

1. to carry out the II. phase of semi-industrial investigations with upgraded semi-products (20 t of SP-A, and 6 t of SP-B) in order to determine the optimal operational conditions for: a) production of dead-burned magnesite, and b) of basic refractory bricks (from semi-product SP-A);

2. to explore the domestic, and foreign (SADCC-, and PTA-) markets, and to prepare a precise MARKET STUDY;

3) the reserves and the quality of Kadoma magnesite (max. 1 % of SiO_2, and max. 4 % of CaO) to be checked and confirmed by GEOLOGICAL SURVEY, Harare;

4) to prepare, if the II. phase of semi-ind.investigations proves to be successful, a feasibility study for complete project;

5) employ the additions of existing staff with Department of Metallurgy, enabling them to specialize in the fields of ceramics and refractories;

6) to provide additional equipment for Department of Metallurgy, enabling more comprehensive investigations in the field of ceramics and refractories to be carried out;

7) to carry out the investigations on the viability of domestic raw materials for the production of high alumina refractories;

8) to provide most important scintific literature (books and journals) for the fields of ceramic and refractories.

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I. INTRODUCTION

A. Background

Refractories belong to the group of strategic materials, which are indispensable for the lining of industrial kilns for the production of: steel, ferro-alloys, non ferrous metals, cement, lime, glass, ceramics, etc. Many countries in the world would like to have their own production of refractories, in order to increase their economical independence, and to improve foreign exchange situation. This is especially the case with the countries, like Zimbabwe, disposing over reach raw material resources, such as: Magnesite, chrome ore, graphite, kyanite, bauxite, silimanite, corrundum, fire clays, etc.

Regular production of Kadoma (Barton Farm) magnesite ore has a content of 3-4 per cent of lime, and 0.5-1.0 per cent of silica, respectively. While such a silica content is acceptable for the products out of natural magnesites, the mentioned lime content is not only very high, but, in addition to that unevenly spread as well, making thus the use of such dead-burned magnesite for the production of refractories very limited. This because of the fact, that the high lime content reacts with the humidity from the air, causing the desintegration of shaped products.

Kadoma mine exploits natural magnesite for almost two decades, but this is prevailingly used for the manufacture of refractories outside of Zimbabwe. This ore has a typical appearance of a breccia, containing magnesite fragments, white to grey in colour, binded by the dark grey material in form of a nettwork of veins. Magnesite fragments are of satisfactory purity. Binding material, consisting of a mixture of dolomite and magnesite with the higher concentration of lime, shows higher content of lime than the ore itself.

The size of magnesite fragments vary from a few milimetres up to a few centimetres. The ore is pretty hard, and during crushing the cracks extend mostly through the magnesite fragments, which will be thus splitted in two or more pieces. The smaller magnesite fragments, after crushing, stay being binded by the bond, as described above. This is the main reason why the known methods, based on the gravity, cannot be succesfully used for the beneficiation of Kadoma magnesite ore.

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In order to obtain a stable dead-burned magnesite from Kadoma ore, some investigations have been carried out, under the leadership of the experts, in the Research Institute of MAGNOHROM, at Kraljevo (YUGOSLAVIA), and the results published in the "PRELIMINARY STUDY OF THE TECHNOLOGICAL VIABILITY OF ZIMBABWEAN MAGNESITE AND SOME CHROME ORES FOR THE PRODUCTION OF BASIC REFRACTORIES", April 1983, (1). During these investigations, by applying the process of homogenizing and stabilizing, a stable dead-burned magnesite of commercial quality, containing about 88 per cent of MgO, has been obtained. Owing to its properties, this dead-burned magnesite can be used for the production of basic refractories of usual, commercial grade.

The production of high quality magnesite-, magnesite-carbon-, and magnesite-chrome bricks from Kadoma magnesite would be possible, only if this ore could be up-graded by means of a process, which could noticeably reduce its lime content.

The authors of this report have carried out laboratory scale investigations in Zimbabwean Institute in the time from December 1984 through March 1985, and developed the new process of "selective hydration". The results have been published in their Terminal report: "INVESTIGATIONS ON THE POSSIBILITY OF BENEFICIATING OF LOCAL RAW MAGNESITE FOR THE PRODUCTION OF BASIC REFRACTORIES (DP/ZIM/83/006), (2).

B. Up-grading of raw magnesite by selective hydration

The applied process of selective hydration is based on the release of pure magnesite fragments from the binding material. In order to achieve this, the ore should first be calcined, and the magnesite ($MgCO_3$), and dolomite ($MgCO_3.CaCO_3$), respectively, decarbonised according to the reaction:

$$MgCO_3 \longrightarrow MgO + CO_2$$

$$MgCO_3.CaCO_3 \longrightarrow MgO + CaO + 2CO_2$$

Chemical properties of thus obtained MgO, and CaO, respectively, differ essentially, especially in respect of their reactivity under the influence of water and/or saturated water-vapour. Lime is much more reactive, and selective hydration process makes use of this property.

The process consists of following:

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- Kadoma magnesite ore, produced at present by selective mining, with a silica content of up to 1 per cent, and lime content of up to 4 per cent, is crushed primarily from 250 mm down to 60 mm, and then down to 25 mm; the ore will be screened out twice: after primary crushing on the sieve with the apertures: 60x60 mm, and after secondary crushing on the sieve with the appertures: 25x25 mm, and 3x3mm, respectively. Regular sizing for deliveries to refractories industry is the ore: - 25 + 3 mm. The tailings, - 3 mm (about 15-17 per cent of the total ore quantity), are stock-piled at the mine, as unusable rejects for the time being;

- Three sizings of Kadoma crushed and washed magnesite ore: a) - 60 + 25 mm, b) - 60 + 3 mm, and c) - 25 + 3 mm are calcined in the rotary kiln at trial working temperatures between 820°C and 1050°C;

- Calcined Kadoma magnesite, cooled down to room temperature, under continuous mixing in an appropriate mixer is wetted with 5-6 wt. per cent of water and, after one minute, transferred in a steel container, and kept covered (with a lid) for at least 24 hours (soaking time). During this time period selective hydration takes place: water first reacts with CaO, forming $Ca(OH)_2$. This reaction is exothermic one, generating heat, which increases the temperature of the material, and creates water vapour. The latter penetrates in the micro-, and macro-cracks and pores of the calcined material, and reacts with the lime, contained by the binding material. This reaction, which is followed by great increase of the volume, causes desintegration of the particles, having higher content of CaO. In this way the magnesite fragments are released, but some of them would also slightly react, just on the surface, keeping their original shape and size, and becoming somewhat harder.

- After the soaking the hydrated material is quite dry, and can be screened out without difficulties on a double-deck screen. The coarsest class of the material shows the lowest lime content, and the finest class - the highest lime content. Lime content of the middle class is somwhere in between. Chemical composition and recoveries of the individual classes can be adjusted, by using the screens with different appertures.

By applying selective hydration method of beneficiation of raw magnesite from Kadoma mine in laboratory scale investigations, following recoveries of semi-products, and their lime contents have been achieved:

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Semi-product	Fraction, mm	Recovery, %	CaO, wt. %
SP-A'	- 16.o + 3.o	35-40	2.5 - 3.o
SP-B'	- 3.o + 1.18	30-35	4.o - 5.o
SP-C'	- 1.18	28-32	10 - 15
Starting Material	- 25.o + 0	100	6.75

The obtained semi-products "A" , and "B" , have been used for carrying out of additional laboratory scale investigations, aimed at obtaining high quality dead-burned magnesite, m a g n e s i t e - , and magnesite-chrome bricks, respectively. The results have been published in the Final Report, UC/ZIM/85/119, June 1986 (3), with the main conclusion: "the results of laboratory scale investigations are very positive. Properties of obtained dead-burned magnesite, and of test bricks can be compared with the highest grades of basic refractories produced out of natural magnesites.

Despite of all efforts, done during earlier long lasting investigations, no one conventional beneficiating method has given positive results, when applied to Kadoma magnesite, due to specific characteristics of this ore. The only ones left, which could be applied successfully for up-grading of Kadoma magnesite, are:

- Selective Hydration,
- Flotation, and
- Chemical processes.

As far as the flotation is concerned, it can be said, that only recently the investigations for the reduction of lime content in raw magnesites of Kadoma type had been started. And, the chemical processes are known to be by far most expensive.

On the basis of first estimates, the production costs for one ton of upgraded magnesite (semi-product) by selective hydration should be some - where in the middle of the known processing methods, given below in the sequence of increasing production costs:

- Magnetic Separation,
- Optical Separation,
- Heavy Media (Gravity) Separation,
- Selective Hydration,
- Flotation, and
- Chemical processes.

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The results of chemical analyses for the hand selected pure magnesite fragments from Kadoma ore have shown, that one part of its $CaCO_3$ (corresponding to about 1.o-1.25 per cent of lime), has been finely and evenly distributed through the magnesite fragments. This part of lime could be eliminated from the ore only by chemical process. The other processes cannot reduce the lime content in the calcined or dead-burned Kadoma magnesite below 2.o-2.5 per cent. Practically, selective hydration, and flotation, respectively, could reduce the lime content, in this particular case, up to a level which is located somewhat above the mentioned values. This because of the fact, that both processes primarily remove the lime originating from the dolomitic binding material.

At the end the main features of the selective hydration process can be summarized as follows:

Advantages:

- Very simple technology, not requiring highly skilled manpower,
- High efficiency in the reduction of lime,
- Very flexible process, ensuring good recoveries,
- Process practically without rejects,
- Relatively low consumption of energy,
- Very small consumption of water,
- No special problems for the protection of environment,
- Low investment costs, through the use of simple equipments

Disadvantages:

- Process cannot use magnesite ore below 5 mm,
- Two steps firing (calcining and dead-burning),
- Lower lime reduction than with chemical process.

C). Purpose of this Mission

Starting from the positive results of previous laboratory scale investigations, a Programme of work (Annex No. 1) has been prepared for carrying out of semi-industrial investigations, aimed at up-grading of Kadoma raw magnesite, containing up to 1 per cent of silica, and up to 4 per cent of lime, respectively, so that it can be used for the production of high quality basic refractories.

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The reasons for having recommanded semi-industrial investigations to be carried out, were very numerous:

- selective hydration is quite newly developed technological process, for which all operational conditions have to be found out in the practice;
- the results from laboratory scale investigations cannot be taken as sufficiently relyable (not only due to great differences in the operational conditions), and must be checked;
- for the preparation of the feasibility study relyable input data, like specific consumption figures, etc., are needed. These can only be collected from semi-industrial investigations;
- necessary quantity of the starting raw materials for semi-industrial production of high quality dead-burned magnesite, and of test bricks, could not have been ensured otherwise;
- the knowledge of the final product properties for a future plant is of outstanding importance for making decision, whether to establish an investment intensive plant or not;
- the most important equipments, necessary for the first phase of semi-industrial investigations, were available in the closest proximity to the magnesite mine.

It was expected, that the experimental work, in its end phase, would enable the obtaining of up-graded magnesite (semi-product "A") for the production of refractories, having following chemical composition:

Semi-product	SiO_2	CaO	MgO
SP-A	1-1.5	3-4	94-95
SP-B	1-1.5	4-5	93-94

If this quality grades of semi-products "A", and "B", would be achieved, second phase of semi industrial investigations in Yugoslavia/EUROPE, as well as the preparation of the feasibility study would be fully justified.

In order to allow the comparison of the mentioned qualitis with the quality grades, obtainable on the world market, in the Table No. 1 (4) the chemical compositions of the dead-burned magnesites, as produced out of : a) crypto-crystalline magnesites, b) large crystalline magnesites (high in iron), and c) sea water and brine, have been shown:

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Table No 1.

Chemical Compositions and Bulk Densities
of Commercial Dead-Burned Magnesites

A) From crypto-crystalline Raw Magnesites (low iron) - in per cent

	A	B	C	D	E	F	G
SiO_2	1.5	1.4	0.8	0.8	1.5	2.5	5.5
Al_2O_3	0.2	0.2	0.2	0.15	0.25	0.2	0.2
Fe_2O_3	0.8	0.6	0.6	0.7	0.6	0.8	0.2
CaO	2.4	2.2	2.4	3.5	2.0	1.5	2.0
MgO	95.5	95.0	96.0	94.5	95.0	94.5	92.0
B_2O_3	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Bulk Density	3.35	3.40	3.35	3.30	3.38	3.35	3.30

B) From large crystalline Raw Magnesites (high iron) - in per cent

SiO_2	1.0	0.9	1.3	1.2	0.8
Al_2O_3	1.0	0.5	0.8	0.6	0.2
Fe_2O_3	5.0	7.5	2.7	1.3	3.2
CaO	3.0	2.7	0.8	1.6	2.95
MgO	90.0	88.0	94.5	95.1	92.9
B_2O_3	0.01	0.01	0.01	0.01	0.01
Bulk Density	3.35	3.25	3.35	3.25	3.25

C) Synthetic Magnesias - in per cent

SiO_2	0.7	0.6	0.5	0.3	0.15
Al_2O_3	0.2	0.2	0.15	0.06	0.05
Fe_2O_3	0.2	0.2	0.15	0.06	0.06
CaO	2.2	0.7	2.2	1.0	0.4
MgO	97.0	98.0	97.0	98.6	99.3
B_2O_3	0.02	0.08	0.04	0.08	0.01
B.Density	3.42	3.32	3.40	3.41	3.37

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By comparing the chemical composition of Kadoma raw magnesite with the data, given in the Table No. 1 , it can be found out, that all its contaminants are present in allowable limits. The only exception represents its lime content, which is almost three times higher. However, by efficient lime reduction, which will be followed by corresponding increase of MgO-content, the chemical composition of its dead-burned products can be brought to the necessary level, so that its quality will be competitive.

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At the requests of the Ministry of Mines, and of the Ministry of Economic Planning and Development of Zimbabwean Government, UNIDO arranged for the authors to assist the Government, and to carry out semi-industrial investigations in the period 25.04.1987 through 22.08.1987, a total of 17 weeks. The main objective of two experts was to explore technical viability of a beneficiation technology for raw magnesite from Kadoma mine, developed earlier, to reduce its high lime content, and to collect as many specific consumption figures for the process as possible, needed for the preparation of the feasibility study.

D . Mission Support

The mission was based at the DEPARTMENT OF METALLURGY (DoM), Ministry of Mines, Harare. Counter-part team consisted of:

1) Mr. J.J. Bungu, BSc, Msc (U.K.), Director of the above Department, who was assigned also as National Project Firector;
2) Mr. J. Mapiravana, BSC (1983, University of Zimbabwe - Chemistry + Geology), Chief of Ceramic Department in the Dep.of Metallurgy,
3) Mr. L. Mareya, BSc (1985, University of Zimbabwe - General Degree).

Mr. J.J. Bungu, whom to especial thanks are due, actively participated in all important discussions, particularly in those on the Programme of Work, and on the rearrangements of the time schedule, introduced by the RIO TINTO Managements. During the work of the experts in RIO TINTO plant, at Eiffel Flats, Mr. Bungu had regular daily contacts, giving his suggestions prevailingly through Mr. Mapiravana. In addition, Mr. Bungu has paid the visits to the duty station in Eiffel Flats almost every week.

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Curriculum vitae for senior counter-part staff, Mr. J. Mapiravana (Annex No. 2) , and Mr. L. Mareya (Annex No. 3), who have assisted the experts for the whole duration of this mission, and whom to an everyday's on the job training has been given, are attached to this report. Mr. Mapiravana was responsible for the official relations with the management of RIO TINTO, and with the workers, rendering services during the semi-industrial investigations. Both, Mr. Mapiravana, and Mr. Mareya, deserve full recognition for their devoted work on the realisation of the project.

Experimental work has been carried out in RIO TINTO plant, at Eiffel Flats, on the basis of permission, granted by Mr. F.C. Boehmke, Executive Director (Development), and Mr. A.J. Dorrenboom, Operations Director. Very valuable support, also, has been received from Mr. M.Van Zyl, Workshop's Forman, at Eiffel Flats plant, who continuously took care of proper servicing and maintenance of equipments, used by the experts.

Most useful support has been given by the INSTITUTE OF MINING RESEARCH, at the University of Zimbabwe, Harare (Director Prof Dr. K.A. Viewing, Mr. T.R.C. Fernandes, and Mr. B. Witkin), where very many determinations and chemical analyses have been done, and for which our sincere thanks are due.

The authors have been enabled to make many visits to existing magnesite mine, at Barton Farm - Kadoma (Manager: Mr. Odendaal), for collecting of representative samples. For the support by senior staff of the mine in delivering the samples in shortest period of time, we would like to thank them all.

The authors gratefully acknowledge the enthusiastic help, provided by so many individuals. Without such support all these investigations could not have been accomplished in time.

Especial thanks are due to Mr. A. Olsen, JPO at UNDP-Office, Harare, for constant support and useful instructions.

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On 30. June 1987, Dr. A. Ambatchew, UNDP-RESREP, Harare, Mr. C. Ushewokunze, Perm.Secretary, Min.of Mines, Harare, and Mr. D.Litvinović, Ambassador of SFRY, in Harare, visited the experts at Eiffel Flats, in order to get full acquaintance with the progress of experimental work, and with the possible future phases in the realization of the project.- On 06. August 1987, Mr. Murangari, Dep.Perm.Secretary, Min.of Mines, Harare, also visited the experts, with the same scope.

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E. Preparatory work and hindrances during the mission.

1). In order to enable counter-part team to carry out the preparatory work, and to provide the equipments, necessary for semi-industrial investigations - on time, two lists have been submitted by the experts:

- List of the equipment to be provided for semi-industrial investigations - with the Final Report, in June 1986 (3), (Annex No. 4), and
- List of Recommandations how to prepare the rotary kiln, at Eiffel Flats, for calcining of raw magnesite - in December 1986 (Annex No. 5).

Due to justifiable reasons it has not been possible to get everything accomplished before the arrival of the experts, so that they also had to take care with the National Project Director, and to make provision that their work can start woithout delay.

Despite of all efforts, there were problems to be solved, and the hindrances to be eliminated during the mission. Some of them, being of greater importance, will be mentioned hereunder, and the solutions and/or way-outs described.

Before that it must be empasized, that on the basis of the announcement of RIO TINTO's Management, additionally made at the beginning of June, the rotary kiln, which had been given at disposal for calcining of raw magnesite, could have been used only untill 22nd June 1987. After that date, it was notified, RIO TINTO needed this kiln for their own purposes, without any possibility to eventually make use of the same in a later period of time. So, there was no other choice, than to use the kiln in the time available.

2). The existing chemical laboratories in Zimbabwe did not have very much experience with the chemical analyses of raw magnesite, and of calcined, and hydrated magnesite, respectively. Due to that, some discrepances happened to occur. Some of the results were not logical at all.

In order to overcome this problem, sources of mistakes have been thoroughly discussed with the relevant laboratory chiefs, and the instructions given how to apply the standard analytical methods.

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In order to avoid the risk of getting unrelyable results, the specimens for important analyses have been submitted to three chemical laboratories. All other specimens have been submitted to at least two of them.

Evaluation of the results for chemical composition has been done on the basis of the average values of the results from all three, but at least from two different chemical laboratories. In exceptional cases, some of the results, being very unlogical, have not been considered.

3). During the determination of the distribution of Mg , Ca , and Si , in the magnesite ore, photo-camera on the Electron-Micro-Probe-equipment was not in a good repair. Because of that, it was necessary to visually estimate the mentioned distribution on the monitor. In addition, the concentration of Mg , and Ca in the magnesite fragments, as well as in the binding material, has been determined by the device for energy-dispersive analyses of the electro-micro-probe equipment.

4). The rotary kiln, before being used for the calcining of raw magnesite, has not been run for at least one year. Therefore, it was necessary to conduct pretty extensive maintenance work, in order to get it usable for this particular purpose. Additional problem was the fact, that the refractory lining bricks had been almost saturated by chrome tanning salts, processed earlier in the same kiln. And, the alkaline chrome salts represent unpleasant contaminant for the magnesite products.

Cleaning up of the rotary kiln refractory lining from the infiltrated salts has been conducted by calcining of raw magnesite for more than 24 hours, at the working temperature of 900°C . During this time, a new coating has been formed on the refractory lining, consisting of MgO-CaO-Al_2O_3-SiO_2-compounds.

Due to the shortage of the adequate refractory bricks for the lining of the entrance part of the rotary kiln, about 3 meters in length, it was jointly decided with the Management of RIO TINTO, to cool this part of the kiln with sufficient quantity of water - during its running. This, on the other side, had a very negative influence on the consumption of fuel oil, making it noticeably higher.

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5). For the process of up-grading by selective hydration, working temperature for the calcining of raw magnesite is of outstanding importance. The working temperature should be somewhat higher than the temperature of decomposition of calcite, but, on the other side, somewhat lower than the temperature, at which a noticeable densification of calcined magnesite begins.

During the trial tests the working temperatures have been measured both, by Pt/PtRh-thermocouple, which has been built-in into the rotary kiln, as well as by means of an optical pyrometer - "OPTIX".

Litre-masses of magnesites, calcined during the trial tests at precisely measured working temperatures between 820° and 1050°C , have been found to be very useful and quick method for the determination of the calcining grade of the material. This, because of the fact that a good correlation between the litre-mass, on one side, and the calcining temperature, on the other, exists.

At the beginning of the main calcining test the existing thermocouple was broken. Due to the request of RIO TINTO's Management to set this kiln free for their use in a very short period of time, it was not possible to wait untill the newly provided Pt/PtRh-thermocouple be calibrated. Under such condition, it was jointly decided with the counter-part team, not to shut down the kiln, but to measure the temperatures by both, the new thermocouple, and optical pyrometer parallely. In addition, the litre-masses of calcined magnesite have regularly to be determined, every full hour.

6). On the basis of the results, obtained from the trial tests, it would have been better to use for screening out of the hydrated material in the main test following wire-sieves: a) for the upper position the sieve with the appertures: 3.15x3.15 mm, and for the lower, the sieve with the appertures: 1.4x1.4 mm. Unfortunately, both sieves were not available on the market. Due to that, for the main test the sieves as follows had to be used: 3.4x3.4 mm in the upper position, and 1.6x1.6 mm in the lower. This slight change in the appertures of the sieves has not caused noticeable change of the results, obtained in the main test.

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II. RAW MAGNESITE FOR TRIAL TEST

A. Collecting of Representative Samples.

For the trial tests of semi-industrial investigations two representative samples of raw magnesite have been collected, as follows:

a) Sample RM 3-25 mm, about 40 t of crushed, washed and screened-out ore, from the railway site, which has been prepared for delivery to a foreign customer, having total quantity of about 1,500 t ;

b) Sample RM 25-60 mm, about 22 t, representing the "overflow" from the sieve with the appertures: 25x25 mm, after primary crushing of the ore, at Kadoma mine ;

c) Sample RM 3-60 mm, about 12 t, has been prepared in the rotary kiln plant, at Eiffel Flats, by using 75 wt. per cent of the sample a) , and 25 wt. per cent of the sample b) .

All details in connection with these representative samples have been described in the Annex No. 6

III. DETERMINATIONS OF PROPERTIES OF RAW MAGNESITES FOR TRIAL TEST

In order to find out, whether the ore has the same properties as the one from 1984/1985, when the laboratory scale investigations have been carried out, it was requested to determine its following properties:

- Grain Size,
- Chemical Composition,
- Mineralogical Composition,
- DTA, and
- Physical Properties.

A. Grain Size Distribution

In order to ensure the changes of sizing of various magnesite samples to be followed during all phases of technological process, grain size distriburion of all three representative samples has been determined, and the

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results shown in the Table No. 2 . Special attention has been paid to particles below 3 mm, which after calcining in rotary kiln becoma smaller, and represent an useless burden for the process.

Table No. 2 .

Grain Size Distribution of Representative
Samples of Raw Magnesite
(Per cent)

Particle Size / Sample	+ 25	-25+15	-15+10	-10+5	-5+3	- 3
RM 3 - 25	0.2	40.3	17.6	26.8	6.9	8.2
RM 3 - 60	22.5	36.2	14.6	19.2	3.9	3.4
RM 25 - 60	79.0	20.0	1.0	-	-	-

B. Chemical Composition

Special care has been taken to determine the contents of most relevant ingredients, particularly the contents of contaminants, having great influence on the properties of final basic refractories. The obtained results are shown in the Table No. 2 .

Table No. 3 .

Chemical Composition of Representative
Samples of Raw Magnesite
(per cent)

Sample	LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	B_2O_3
RM 3-25	49.93	0.67	0.06	0.14	3.03	46.13	0.04
RM 3-60	49.94	0.74	0.07	0.15	3.04	46.07	0.04
RM 25-60	49.75	0.70	0.07	0.15	3.15	46.14	-

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C. Mineralogical Composition

Macroscopic appearance of the magnesite ore, exploited at present, is the same as in the time of laboratory scale investigations (1984/1985).

It is a typical breccia. On the basis of colour one can differentiate between white and grey breccia, and dark pieces of magnesite ore. X-Ray-Difraction-tests have shown, that the main constituent is magnesite, accompanied by dolomite. but, some quantity of calcite is also present. A typical X-Ray-Pattern for the sample: RM 3-60 has been given on the Figure No. 1 .

Electron-Micro-Probe dispersive analyses have shown, that magnesite fragments represent the material of good quality, with evenly distributed small quantity of lime. Main lime content is intruded in the binding material, which, on the other side, is a mixture of magnesite and dolomite. Distributions of magnesium, and calcium, in three diferent varieties of the ore, are shown on the Fihures No. 2, No. 3 , and No. 4 , respectively.

Distribution of Mg, Ca , and Si, respectively, in the ore has been also tested in the INSTITUTE OF MINING RESEARCH on the ELECTRON-MICRO-PROBE Unit: JOEL 733 SUPERPROBE, with settings as follows:

- Acceleration Voltage 20 kV
- Current $2x10^{-8}$ Amp.

The photographs obtained with the representative samples: RM 3-60 (white and grey breccia, as well as dark ore pieces) were the same as in the tests carried out in 1984/1985.

D. Differential Thermal Analyses

Determinations of the decomposition temperatures of magnesite, dolomite, and calcite, respectively, have been done by means of differential thermal analysis, with alpha-Al_2O_3 as reference material. Increase of temperature between 25^0 and 1000^oC was 10^oC per minute, and sensitivity - 0.2 mV .

Typical DTA-diagrams for raw magnesite are shown in the Figures No. 5 , No. 6 , and No. 7 , respectively.

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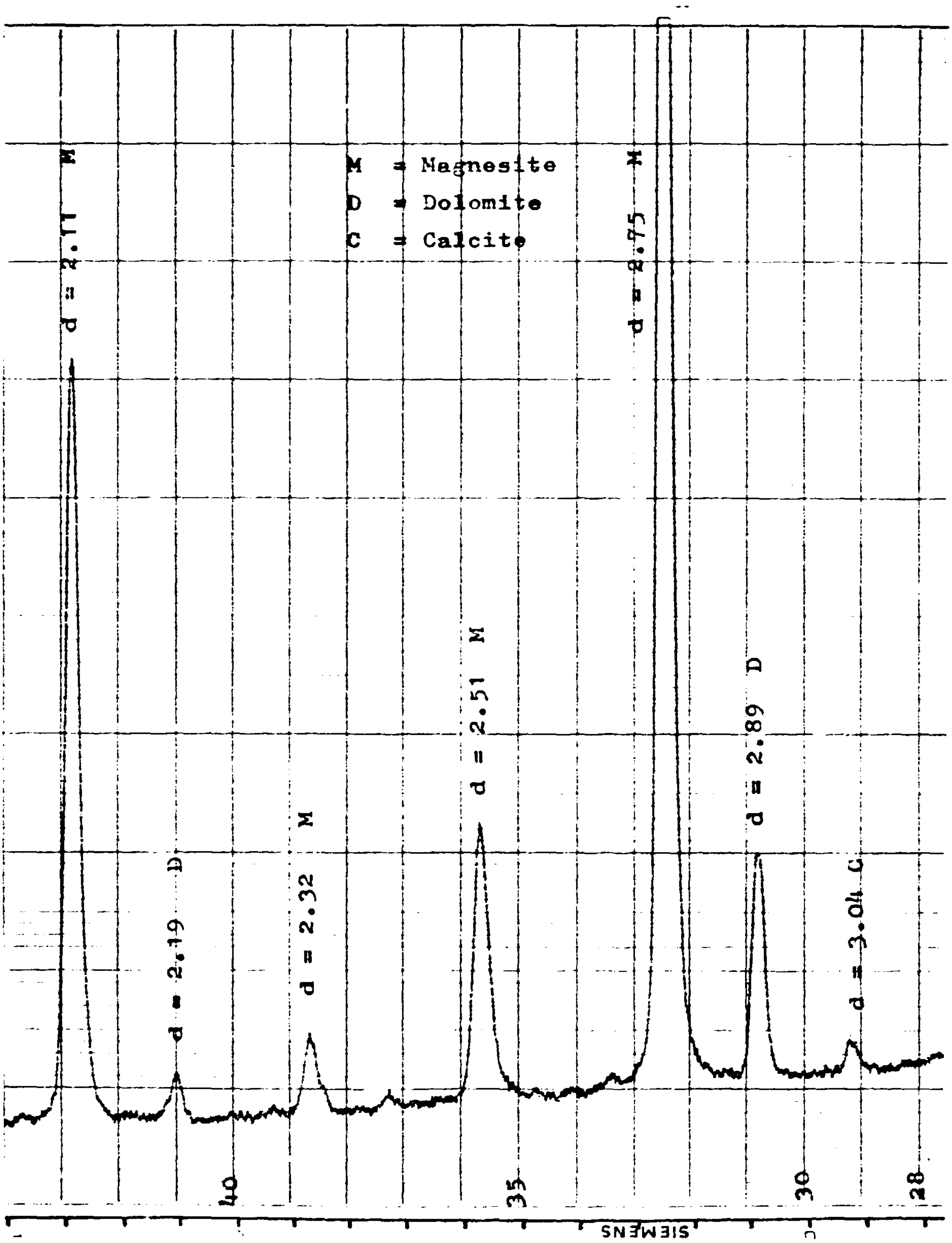

Fig. No. 1 . X-Ray Pattern of Raw Magnesite.
Sample: RM 3 - 60

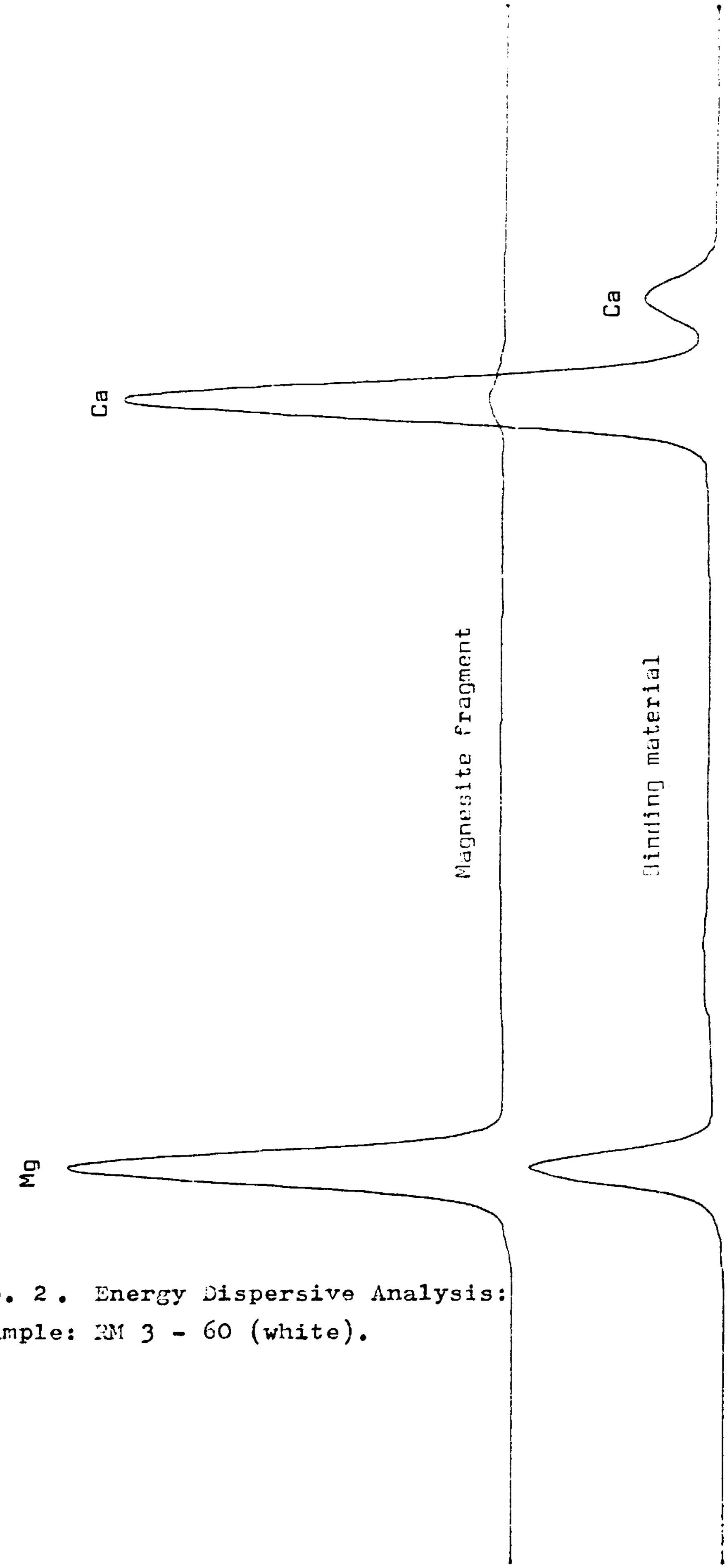

Fig. No. 2 . Energy Dispersive Analysis:
Sample: RM 3 - 60 (white).

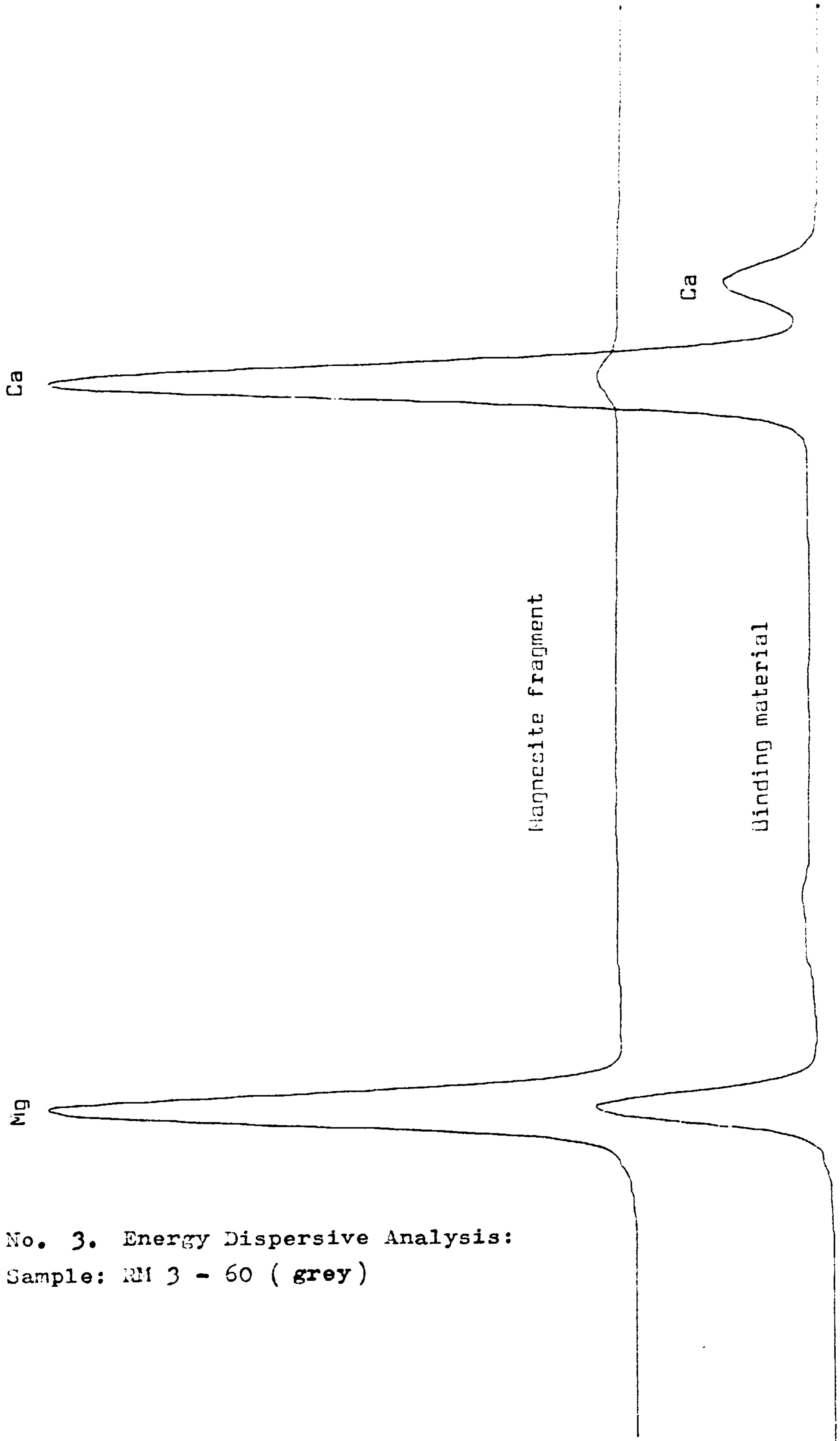

Fig. No. 3. Energy Dispersive Analysis:
Sample: RM 3 - 60 (grey)

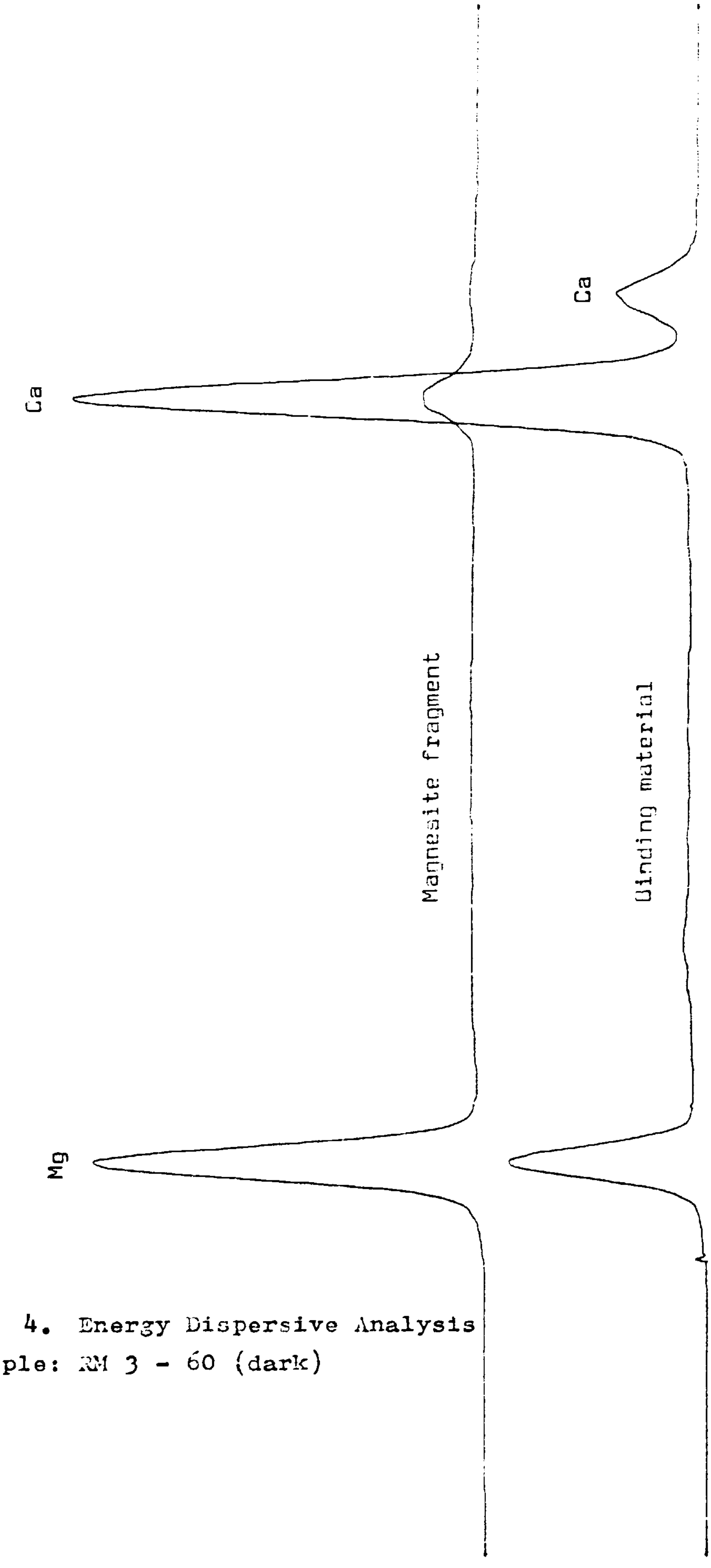

Fig. No. 4. Energy Dispersive Analysis
Sample: RM 3 - 60 (dark)

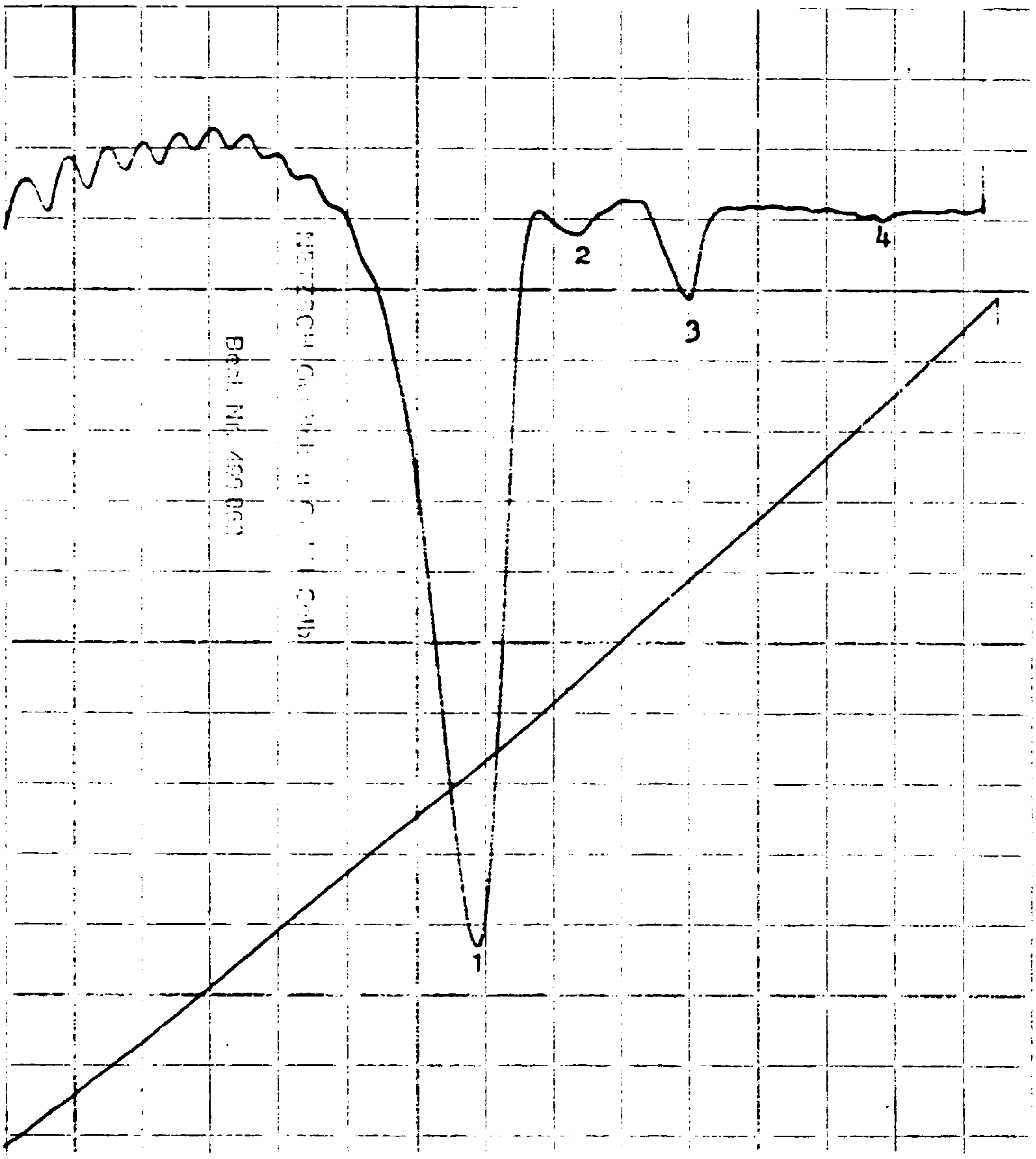

Fig. No. 5.

DTA-Diagram of Raw Magnesite

Sample: RM 3 - 25

1) 600°C - $MgCO_3 \longrightarrow MgO + CO_2$

2) 720°C - $MgCO_3.CaCO_3 \longrightarrow {}^*MgCO_3 + {}^*CaCO_3$

$*MgCO_3 \longrightarrow MgO + CO_2$

3) 800°C - $^*CaCO_3 \longrightarrow CaO + CO_2$

4) 940°C - $CaCO_3 \longrightarrow CaO + CO_2$

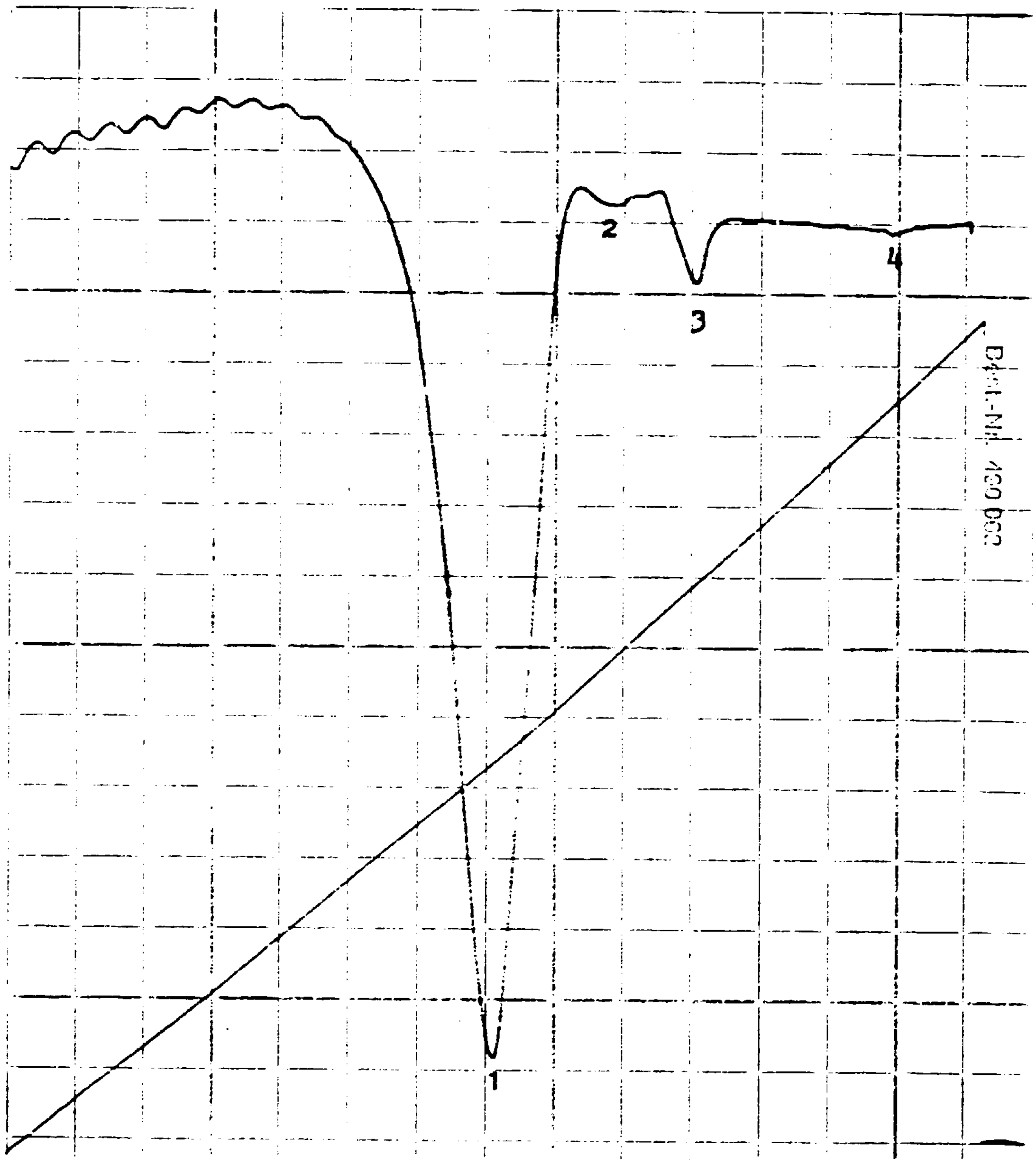

Fig. No. 6. DTA-Diagram of Raw magnesite

Sample: RM 3 - 60

1) 600°C - $MgCO_3 \longrightarrow MgO + CO_2$

2) 720°C - $MgCO_3.CaCO_3 \longrightarrow {}^*MgCO_3 + {}^*CaCO_3$

$^*MgCO_3 \longrightarrow MgO + CO_2$

3) 800°C - $^*CaCO_3 \longrightarrow CaO + CO_2$

4) 940°C - $CaCO_3 \longrightarrow CaO + CO_2$

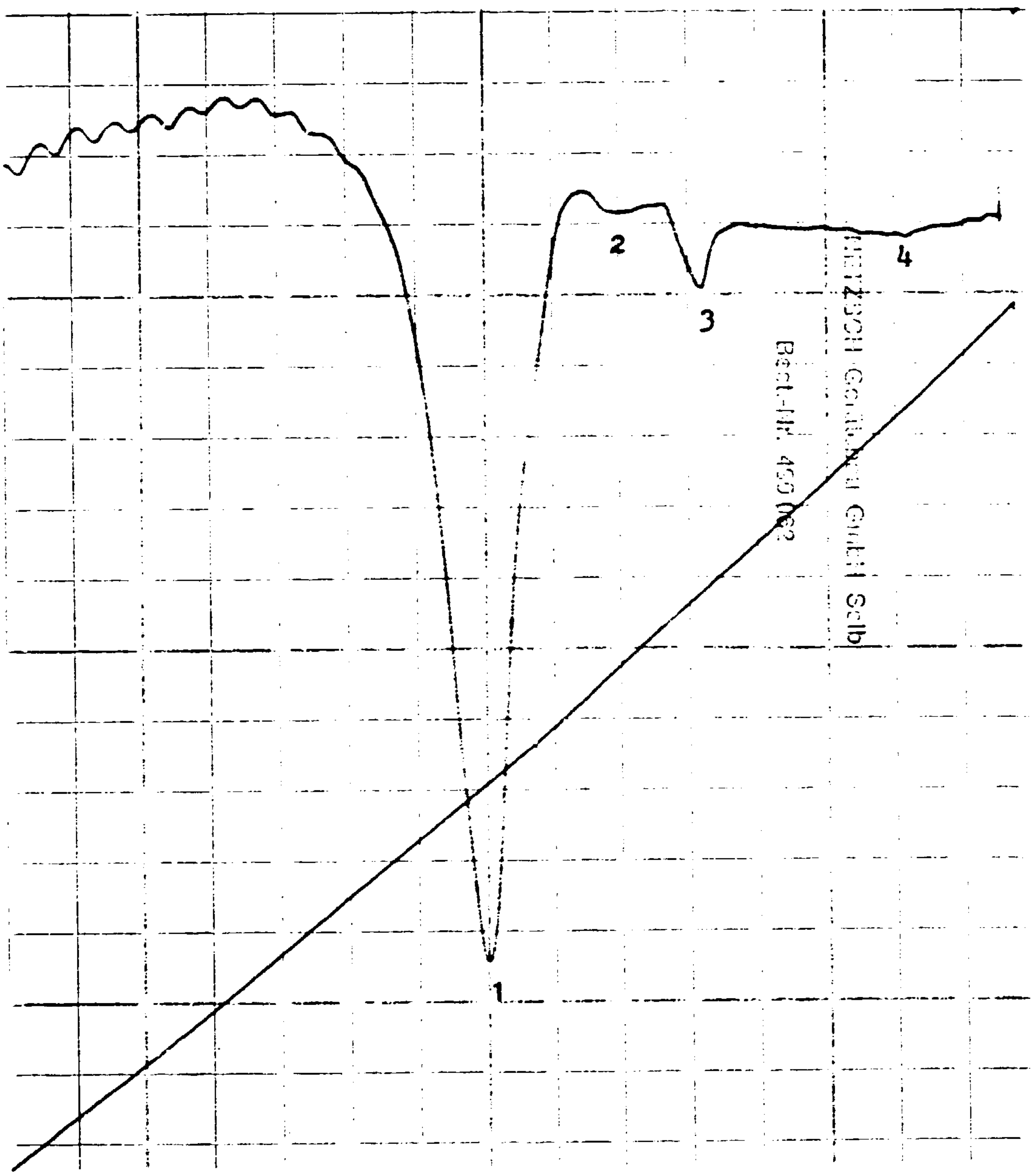

Fig. No. 7. DTA-Diagram of Raw Magnesite

Sample: RM 25 - 60

1) 600°C - $MgCO_3 \longrightarrow MgO + CO_2$

2) 720°C - $MgCO_3 . CaCO_3 \longrightarrow {}^{*}MgCO_3 + {}^{*}CaCO_3$

$${}^{*}MgCO_3 \longrightarrow MgO + CO_2$$

3) 800°C - ${}^{*}CaCO_3 \longrightarrow CaO + CO_2$

4) 940°C - $CaCO_3 \longrightarrow CaO + CO_2$

E. Physical Properties

The values for the following physical properties have been determined, and the results shown in the Table No. 4 :

- Density,
- Bulk Density, and
- Litre-Mass (Annex No. 7 .)

Table No. 4 .

Physical Properties of Raw Magnesites

Sample	Density g/ccm	Bulk Density g/ccm	Litre-Mass kg/lit.
RM -25	2.96	2.91	1.52
RM 3-60	2.97	2.91	1.55
RM 25-60	2.97	2.92	1.47

F. Evaluation of Results

Grain size composition of raw magnesite sample RM 3-25 is very similar with that one from 1984/1985. As a general remark it can be said , that the content of particles below 5 mm is pretty high, amounting to about 15 per cent.

This is not the case with the sample RM 3-60 , due to the participation of the particles between 25-60 mm (25 wt. %). However, the calcining and the processing will show, how this coarser particles are going to behave during the treatment.

Chemical composition of all representative samples of raw magnesite was good, and within usual limits for the production of mine in the last 5-6 years. The internal specification, not to exceed the contents of silica (max. 1 per cent), and of lime (max. 4 per cent), respectively, have been strictly kept.

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There is no evidence about noticeable changes neither in respect of macro-, and micro-structure, nor in respect of the distributions of Mg , Si , and Ca , respectively. The only slight difference has been registered from the X-Ray-difraction test, showing occurence of small quantity of calcite, in addition to the main mineral - magnesite , and to the acompanying mineral - dolomite.

Distribution test for Mg , Si , and Ca , respectively, has confirmed, that the magnesite fragments represent the material of good quality (with small quantity of calcium evenly spread), and that prevailing quantity of Ca is contained in the binding material in form of dolomite. Silica content is rather low, and also evenly distributed through the ore body.

DTA-test has shown, that the decomposition temperatures are as follows:

1) for magnesite - at 600°C
2) for dolomite - at 720°C
3) for $CaCO_3$ (created from dolomite - at 800°C
4) for calcite - at 940°C.

The intensity of the "peaks "3" , and "4" (Figures No. 5 , No. 6 , and No. 7) from DTA-tests confirmed, that the main bearer of lime in the ore was dolomite, and calcite being only a sporadic mineral.

Physical properties of raw magnesite were also within the values , usually, found for this type of the ore.

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IV. INVESTIGATIONS - TRIAL TEST

A. Calcining of Raw Magnesite

Trial calcining tests were aimed at finding out of optimal operational conditions for the main calcining test, as for instance:

1) Working temperature for rotary kiln,
2) Sizing of raw magnesite,
3) Appropriate feed of the kiln,
4) Handling of calcined material,
5) Organization of process control.

With the Programme of Work only three working temperatures have been planned, i.e.: 900°, 1000°, and 1100°C. However, it was decided at the site to enlarge the working temperature levels, introducing: 820°, 850°, 870°, and 1050°C, and ommiting 1100°C. The temperatures below 900°C have been used in order to test the behaviour of the magnesite in the region, where $CaCO_3$ out of dolomite is already decomposed, and calcite still keeping original form. The performances of the kiln, as well as the existing refractory lining, did not allow to raise the working temperature up to 1100°C. Because of that, the temperature of 1050°C has been chosen instead.

In order to investigate the influence of the sizing of raw magnesite on the properties of calcined material, all three ore classes, obtainable from the existing mine crushing equipment, have been used, i.e.: 3-25 mm, 3-60 mm, and 25-60 mm.

The feeding of the kiln has been adjusted in accordance with the performances of the rotary kiln, and with the calorific value of the fuel oil, and varried between 10.0 and 16.8 tons a day.

For the calcining of magnesite the rotary kiln, existing in RIO TINTO's plant, at Eiffel Flats (very close to Kadoma magnesite mine (about 16 km), has been used. Basic characteristics of this kiln have been shown on the sketch (Annex No. 8). The refractory lining, having the thickness of 130 mm, has been made with locally produced fire clay bricks (about 40 per cent of alumina). At the entrance end the shell of the has got a prolongation of additional 3 meters. This part of the kiln

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has not been lined with the bricks. In order to avoid the deformation of the shell at this place, it had to intensively be cooled by means of an aboundant water shower.

The rotary kiln, being without the cooler, could not recuperate the heat. Due to that, the secondary air could not have been preheated. Lack of recuperation, unsuitable regulation of fuel, big differencies in the daily and night temperatures, made it extremely difficult to keep the working temperatures within narrow limits, and to ensure an uniformly calcined product.

Working temperatures of the kiln have been measured by means of a thermocouple (Pt/PtRh), built in into the kiln, at a distance of 1.90 m from discharging end. In addition, an optical pyrometer has been used as well.

Previously, the rotary kiln has run at a speed of one rotation per 12 minutes and 10 seconds (= 0.1 r/min). On the request of experts, the speed has been increased to 5 min. and 11 sec. per one rotation, in which way much better condition for the calcining process has been ensured,(0.2 r/m).

During the tests following data have been recorded, i.e.:

- Quantity and Sizing of the Kiln Feed,
- Consumption of the fuel oil,
- Consumption of the power,
- Quantity of the produced calcined material, and
- Working temperature.

The summary of these data has been given in the Table No. 4 .

Very hot calcined material, coming out of the kiln, has been stock-piled on the concrete floor, lined with the steel plates. After having reached the room temperature, calcined magnesite has been packed in plastic bags, each one wighing 50 kg.

For the control of properties of calcined magnesite, following determinations have been carried out:

- Reactivity,
- Grain Size, and
- Chemical Composition.

Obtained results are shown in the Table No 5 , No. 6 , and No. 7 , respectively.

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Table No.5.

TECHNOLOGICAL DATA FOR TRIAL CALCINING TEST

Data / Sample	Feed kg	Avarage T/°C	Production, kg	Reactivity T/°C *
CM 3-25/820	1,400	827	543	118
CM 3-25/850	1,400	845	640	118
CM 3-25/870	700	860	316	122
CM 3-25/900	5,260	902	2,422	115
CM 3-25/1000	6,300	980	1,920	111
CM 3-25/1050	3,360	1046	1,242	40
CM 3-60/900	4,080	893	1,700	122
CM 3-60/1000	6,440	1005	2,581	120
CM 3-60/1050	2,320	1038	1,078	52
CM 25-60/900	3,640	896	1,629	111
CM 25-60/1000	3,290	994	1,696	117
Total	38,190		15,767	

* = After 1 hour.

Table No. 6 .

Grain Size Distribution of Calcined Magnesites

(Per Cent)

Sample	+ 25	-25+15	-15+10	-10+5	-5+3	- 3
CM 3-25/820	0.0	4.5	4.3	24.4	16.8	49.9
CM 3-25/850	0.0	2.8	2.4	25.8	17.6	51.4
CM 3-25/870	0.0	2.3	4.0	25.2	18.8	48.3
CM 3-25/900	0.7	10.8	8.8	28.3	20.8	30.6
CM 3-25/1000	0.0	2.9	2.5	21.3	15.4	56.9
CM 3-25/1050	0.0	2.4	5.0	25.9	18.6	47.9
CM 3-60/900	10.7	13.8	9.9	20.8	13.7	31.1
CM 3-60/1000	1.8	9.8	6.1	24.8	16.1	41.0
CM 3-60/1050	1.8	9.8	6.6	28.9	15.3	37.5
CM 25-60/900	25.3	19.5	11.0	15.5	10.1	18.6
CM 25-60/1000	3.2	19.2	6.4	19.6	10.4	40.0

Table No. 7 .

Chemical Composition of Calcined Magnesites
(Per Cent)

Sample	LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
CM 3-25/820	1.88	1.00	0.08	0.20	5.91	90.93
CM 3-25/850	1.20	1.08	0.08	0.16	6.12	91.36
CM 3-25/870	0.80	1.39	0.12	0.21	5.95	91.53
CM 3-25/900	0.74	1.18	0.15	0.17	6.53	91.23
CM 3-25/1000	0.60	1.43	0.09	0.17	6.24	91.47
CM 3-25/1050	0.41	1.40	0.11	0.13	6.09	91.85
CM 3-60/900	1.40	1.50	0.13	0.17	5.80	91.10
CM 3-60/1000	0.80	1.30	0.14	0.17	6.60	90.99
CM 3-60/1050	0.61	1.43	0.10	0.16	6.28	91.42
CM 25-60/900	3.48	1.01	0.12	0.15	6.32	88.92
CM 25-60/1000	0.80	1.10	0.10	0.15	6.50	91.35

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Under the reactivity the temperature is understood, which will be reached by the calcined magnesite, after having been wetted by 5-6 wt. per cent of water. The temperature has to be taken after 1 hour , and after 2 hours of soaking, in the covered container.

Procedure: In a stainless steel container (D = 25-30 cm, and H = 40-50 cm), positioned at an angle of about 25° in a rotating device (25-40 rounds per minute), put 10 kg of calcined magnesite (having about 25°C), and add 5-6 wt. per cent of water, under continuous rotating of the container. Keep the container rotating for one additional minute, take it down from the device, and cover with a steel lid. After a soaking of 1 or 2 hours (depending on the reactivity of the material to be tested), the temperature should be measured by a mercury thermometer, with a measuring range of up to 200°C, which should be pushed about 10 cm deep in the calcined material.

Mineralogical composition of the magnesites, calcined at 900°C, and 1000°C, respectively, has been tested by X-Ray difractometer. The two mentioned temperatures are very characteristic due to following reasons: at 900°C the decomposition of $MgCO_3$, as well as of $CaCO_3$ (which has been created from dolomite, has been finished; calcite should stay in unchanged condition, because its decomposition temperature has still not been reached.

On the XRD-Pattern (Fig. No. 8) for the sample CM 3-25/900 following minerals have been registered: periclase (MgO), lime (CaO), and portlandite /$Ca(OH)_2$/. The presence of $CaCO_3$ originating from calcite has not been registered, probably due to its small content, and due to the fact that its crystal structure has been destroyed. On the XRD-Pattern for the sample CM 3-25/1000 (Fig. No. 9), following minerals have been registered: periclase, Lime, and portlandite. But, lime reflexion at d = 2.40 is more intense, confirming that the recrystalization of CaO has taken place, with possible formation of calcium silicates. Above 1000°C calcined material is expected to show lower reactivity values.

During the trial test it was consumed:

- 2,318 kWh, and 14,758 litres of fuel oil.

Fuel oil specifications are given in the Annex No. 9 .

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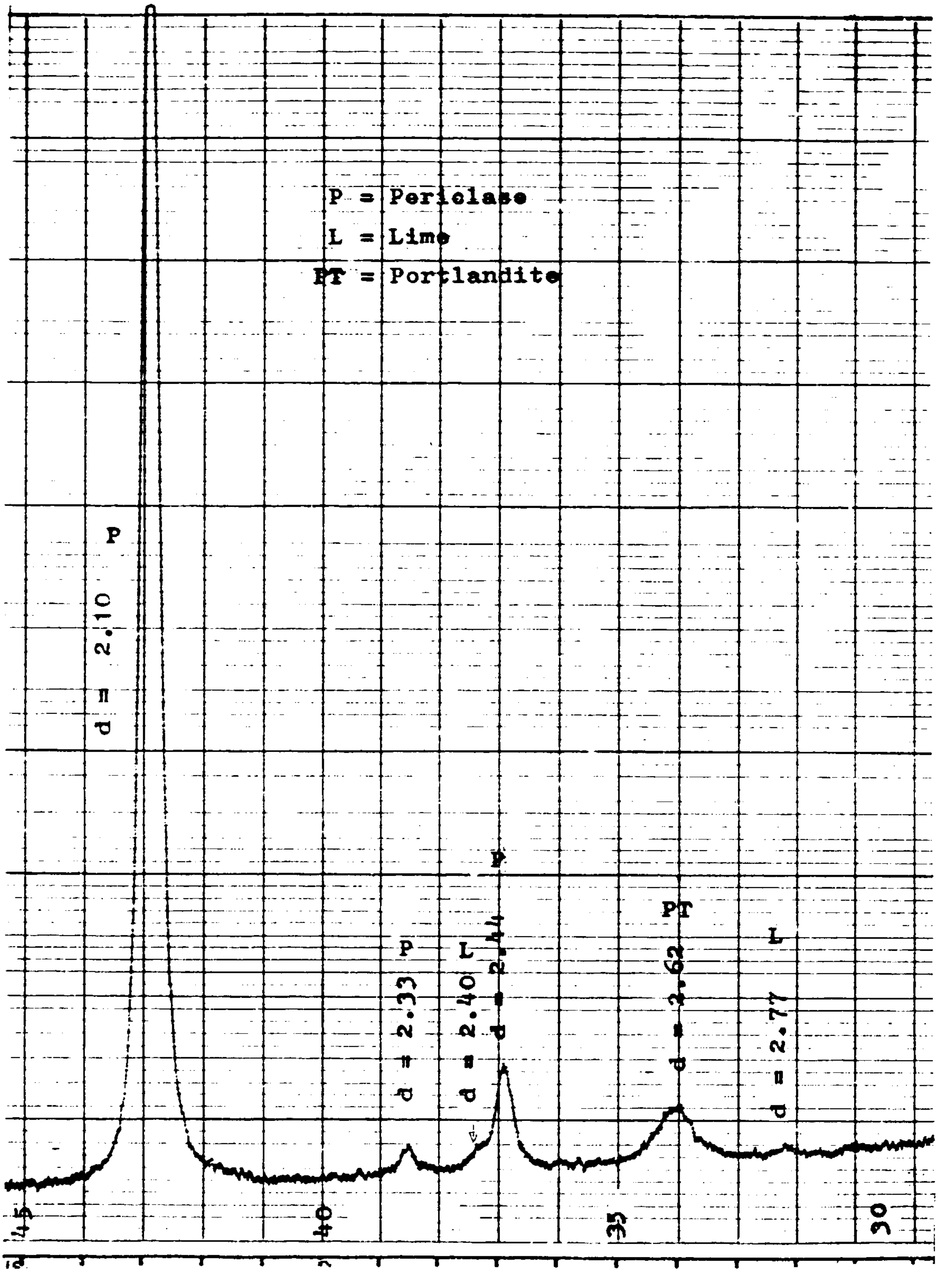

Fig. No.8 . X-Ray-Pattern
Sample: CM 3-25/900.

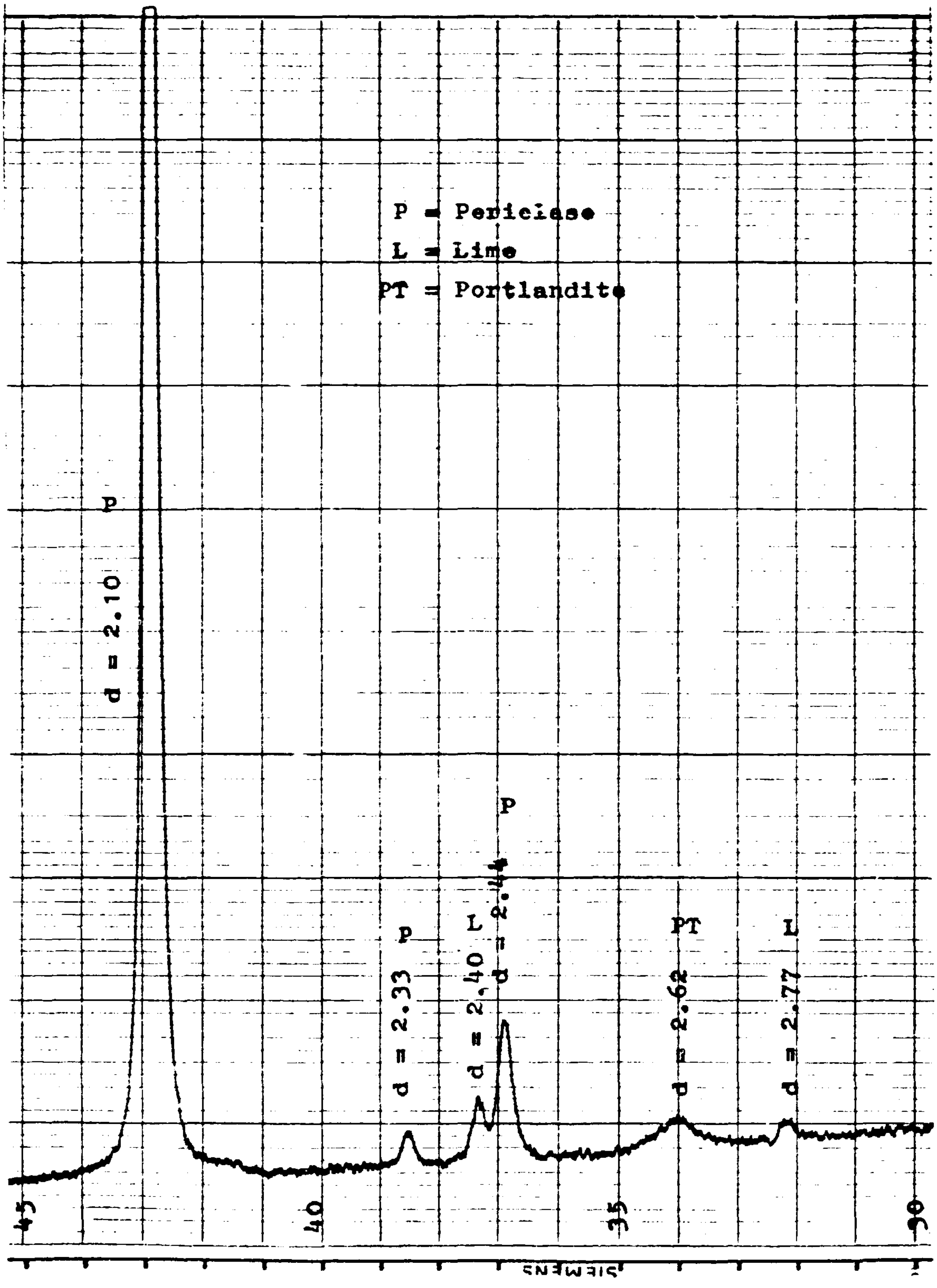

Fig. No. 9 . X-Ray-Pattern

Sample: CM 3-25/1000

B. Processing of Calcined Magnesite

The processing consists of:

- Mixing of calcined material with water,
- Soaking of the wetted material in the covered containers,
- Screening-out of the hydrated material

Characteristics of the used equipments:

- Concrete mixer, having the capacity of 150 litres, and rotating speed of 24 rotations per minute;
- Zinc plated containers, having 75-100 litres capacity, with detachable lids;
- Double-deck vybrating screen (L = 1.5 m; W = 0.9 m); upper wire-sieve appertures: 3.4 x 3.4 mm ; Lower wire-sieve appertures: 1.2 x 1.2 mm ; Inclination: about 18° .

Procedure: add 50 kg of calcined magnesite (= 1 batch) in the running concret mixer, and pour 2.5 litres of water (= 5 wt. per cont), using a fine sprayer. After thorough mixing (one minute), tha batch should be un-loaded in a steel container, and the temperature measured after 1 hour, with a mercury thermometer (range: 200°C). Soaking time should not be below 24 hours. During this time selective hydration takes place. The soaked material should be screened out on a double-deck screen, and split in three classes:

- coarse, above 3.4 mm, designated as + 3 ,
- middle, -3.4+1.2 mm, designated as 13, and
- fine , -1.2 mm, designated as - 1 .

The used double-deck vybrating screen, having a high inclination, and being relatively short, has achived following effects:

- Upper sieve separated all particles above 3 mm ;
- Lower sieve separated separated the particles between 1 and 3 mm,
- Fines, coming through the lower screen, contained the particles from 0 to 1 mm .

The obtained quantities of all three classes have been weighed out, in order to determine the percentage of their recovery. The results are given in the Table No. 8 . The results of chemical analyses are given in the Table No. 9 .

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Table No. 8 .

Technological Data for Processing - Trial Test

Sample	Reactivity T/°C	Semi-Product mm	kg	Recovery %
SP 3-25E/820	118	+ 3	84.8	29.39
		13	120.8	41.87
		- 1	82.9	28.73
SP 3-25E/850	118	+ 3	16.2	33.06
		13	19.7	40.20
		- 1	13.1	26.73
SP 3-25E/870	122	+ 3	145.4	29.59
		13	203.1	41.34
		- 1	142.8	29.06
SP 3-25P/900	115	+ 3	189.0	31.39
		13	240.2	39.89
		- 1	172.9	28.72
SP 3-25P/1000	111	+ 3	252.5	27.85
		13	346.7	38.24
		- 1	307.5	33.91
SP 3-25P/1050	40	+ 3	204.1	27.24
		13	299.9	40.09
		- 1	245.4	32.74
SP 3-60P/900	122	+ 3	272.5	30.64
		13	351.7	39.54
		- 1	265.2	29.82
SP 3-60P/1000	120	+ 3	222.4	27.96
		13	311.2	39.12
		- 1	261.8	32.91
SP 3-60P/1050	52	+ 3	33.3	34.26
		13	41.2	42.38
		- 1	22.7	23.35
SP 25-60P/900	111	+ 3	246.6	37.04
		13	220.4	33.11
		- 1	198.7	29.85
SP 25-60P/1000	117	+ 3	123.2	24.41
		13	195.0	38.64
		- 1	186.4	36.94

Table No. 9.

Chemical Composition of Semi-Products - Trial Test

(Per Cent)

Sample	Semi-Product mm	LOI	SiO_2	CaO
SP 3-25E/820	+ 3	6.46	0.93	3.48
	13	7.51	0.77	5.96
	- 1	8.75	1.30	10.20
SP 3-25E/850	+ 3	6.92	0.31	3.91
	13	6.79	0.83	5.28
	- 1	7.86	1.05	10.32
SP 3-25E/870	+ 3	6.47	0.88	3.68
	13	6.02	0.66	4.87
	- 1	6.90	1.12	10.04
SP 3-25P/900	+ 3	7.36	0.96	3.37
	13	7.48	1.12	5.63
	- 1	8.43	1.76	9.98
SP 3-25P/1000	+ 3	6.52	1.02	3.17
	13	7.09	0.94	4.57
	- 1	8.43	1.01	12.98
SP 3-25P/1050	+ 3	3.01	1.40	3.23
	13	4.16	1.37	4.34
	- 1	6.52	1.33	10.35
SP 3-60P/900	+ 3	6.88	1.75	4.70
	13	6.88	0.39	4.90
	-1	7.82	1.38	9.82
SP 3-60P/1000	+ 3	7.29	1.07	3.70
	13	7.37	1.12	4.61
	- 1	7.80	1.16	11.80
SP 3-60P/1050	+ 3	2.39	1.15	3.47
	13	3.23	1.54	3.58
	- 1	5.63	1.57	11.12
SP 25-60P/900	+ 3	9.13	1.71	5.42
	13	7.67	1.09	4.79
	- 1	8.45	1.07	8.21
SP 25-60P/1000	+ 3	6.68	1.70	5.63
	13	6.87	1.12	5.81
	- 1	7.71	1.07	11.14

C. Evaluation of results

As it can be seen from the Table No. 9 , the average working temperatures have come very close to those ones, planned by the Programme of Work.

Raw magnesite in the sizing 3-25 mm, after being calcined, regardless of the working temperature level, has shown high percentage of particles below 3 mm (31 - 56 %). This comes, at the first palce, from the high percentage of particles below 5 mm in the starting material, which is additionally grinded when moving through the rotary kiln.

Having in mind, that the $CaCO_3$ in the properly calcined magnesite should be completely decomposed, in order to enable the created CaO to actively participate in the process of selective hydration. A very good indicator for the extent of calcination is the loss on ignition of the calcined material. Samples 3-25 mm showed increased values of the ignition loss at the temperatures of 820°, and 850°C, respectively. The samples 3-60 mm, and, especially samples 25-60 mm showed high ignition loss values even at the temperature of 900°C . This due to the fact, that in the cores of the coarser particles the calcining process had not been carried out completely. This is the reasen, why the loss on ignition should be preferably below one per cent.

Results of the chemical analyses of calcined magnesites are shown in the Table No. 6 . They represent average values of the results obtained from three chemical laboratories. A few individual results, showing great, and unacceptable deviation from the other results, have not been considered.

Average content of lime for all 11 samples amounted to 6.21 per cent. Deviation of individual lime content from the average value within ± 10 per cent tolerance.

Macroscopic appearance of the samples: CM 3-25/820, CM 3-25/850 , and CM 25-60/900, respectively, indicated that the calcining process had not been completely finished. The samples: CM 3-25/870, CM 3-25/900, and CM 3-25/1000, respectively, have shown the best macroscopic appearance. And, at the end, the samples: CM 3-25/1050, and CM 3-60/1050, respectively, have given the evidence, that the densification process of the calcined material has already advanced to a noticeable extent.

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XRD-tests of the samples: CM 3-25/900 , and CM 3-25/1000 did not register the presence of $CaCO_3$, in addition to the presence of periclase, lime, and portlandite, respectively.

From the technological data it has been noticed that, depending on the working temperatures, the values for the reactivity varried in great intervals ; the temperatures above 1000°C caused noticeable decrease of reactivity of the calcined material.

Technological data obtained from processing of calcined magnesites (Table No. 7), have given the following average recoveries of the semi-products from the trial tests:

+ 3	-	30.26 %
13	-	39.50 %
- 1	-	30.24 %

In respect of the lime reduction, best results have been achieved with the following samples :

S a m p l e	Real CaO-Contents	Lime-reduction
SP 3-25/900	6.25 ⟶ 3.64	41.8 %
SP 3-25/1000	6.25 ⟶ 3.39	45.8 %
SP 3-25/1050	6.25 ⟶ 3.33	46.7 %

Remark. 6.25 = Average real content of all 11 samples of calcinod magnesites.

Despite of the fact, that the highest lime reduction has been achieved with the magnesite, calcined at 1050°C , this material is not very appropriate for further processing, on the way to the production of dead-burned magnesite. At 1050°C calcined material has been noticeably densified, what could cause serious problems in reaching the adequate density of dead-burned magnesite. In addition, the higher calcining temperature, the higher are production costs, as well. And, this must be avoided as much as possible.

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D. Conclusions

After consideration of the obtained results following operational conditions for the main test have been chosen:

1) Sizing of the raw magnesite, and quantities to be used:

- RM 5-25 mm - about 140 t
- RM 6-32 mm - about 40 t.

2) Working temperatures:

- for RM 5-25 - 950°C ± 10°C
- for RM 6-32 - 970°C ± 10°C

3) Feed of the kiln:

- 85 kg every 10 minutes, or
- 510 kg/hour, or
- 12.24 t/day.

In addition, it was recommanded to increase the feed of the kiln in the last few days to:

- 600 kg/hour, or
- 14.4 t/day.

4) In order to ensure proper control of the working temperatures in the main test, it was recommanded that e new thermocouple with measuring instrument be provided on time, and adequately calibrated, before being used. Additionally, an optical pyrometer should be used, as well. The temperatures have to be measured every 15 minutes, and recorded.

5) As a quick method for the quality control of calcined magnesite it was suggested to check the litre-mass every full hour - at the kiln site.

6) Water quantity, to be added for wetting of calcined magnesite, should be 5-6 wt. %, and the duration of mixing (in the concrete mixer) - one minute.

7) Soaking time for hydrated material should be at least 24 hours.

8) Screening: In order to increase the recovery of semi-product "A", SP-A, it would have been better to build-in in upper position a standard wire sieve with appertures: 3.15x3.15 mm, or even 2.8x2.8 mm. Due to the fact, that the mentioned sieves were not available on the market at that time, it was decided to use the sieve from the trial test, i.e.: 3.4x3.4 mm.

The improvement of the quality of semi-product "B", SP-B, could have been reached by the use of standard sieve: 1.4x1.4 mm in the lower position. Being also not available, the sieve with appertures: 1.6x1.6 mm had to be used.

9) It was recommanded to discard all quantities of calcined magnesite, not having the proper quality.

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V. PRODUCTION OF UP-GRADED SEMI-PRODUCTS

A. Preparation of samples for Main Test

On the basis of the results from the trial tests it was decided to use raw magnesite samples RM 5-25 mm (140 t), and RM 6-32 mm (40 t), respectively. Collecting of these samples has been described in the Annex No. 10 . The sample RM 5-25 has been produced out of the RM 3-25, by screening it out on the screen 5x5 mm - at the kiln site.

For further realization of this project, the ore reserves are of outstanding importance, especially of the ore having not more than 4 per cent of lime, and not more than 1 per cent of silica. That was, also, main reason to recommand in all their previous reports: "the reserves of raw magnesite with Kadoma mine to be checked and confirmed by GEOLOGICAL SURVEY , Harare." This recommandation has also been made after their arrival, on the basis of which one very experienced geologist of GEOSURVEY has paid a visit to the mine, doing general prospection. His finding is attached to this report as the Annex No. 11 .

For both samples, RM 5-25, and RM 6-32, grain size distribution, and chemical composition have been determined, and the results given in the Table No. 10 , and the Table No. 11 , respectively-

Table No. 10 .

Grain Size Distribution of Raw Magnesites
Used in the Main Test (Per cent)

Sample	+ 25	-25+15	-15+10	-10+5	-5+3	- 3
RM 5-25	0.1	45.2	17.8	31.4	4.6	0.9
RM 6-32	26.9	42.2	11.6	17.6	0.7	1.0

Table No 11 .
Chemical Composition of Raw Magnesites
Used in the Main Test (Per cent)

Sample	LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
RM 5-25	49.90	0.76	0.06	0.14	3.01	46.12
RM 6-32	49.44	0.57	0.04	0.14	3.04	46.77

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B. Calcining - Main Test

Calcining of the magnesite has been carried out under the operational conditions, given in the conclusions from the trial test (page 42). All efforts have been done in order to keep prescribed conditions in the narrowest possible limits. The temperature has been measured by optical pyrometer. As the first quality control the determination of litre-masses every full hour has been used. It has been recommanded to keep the litre-mass values in the range between 1.0 and 1.2 kg per litre.

During the main calcining test following data have been recorded:

- Feed of the rotary kiln,
- Working temperature,
- Fuel oil consumption,
- Production of calcined material, and
- Power consumption.

Summary of technological data has been given in the Table No. 12 , and the specific consumption figures in the Table No. 13 , respectively.

Results of the grain size distribution, as well as of chemical compositions, based on the daily production (= one composite sample), are given in the Table No. 14 , and No. 15 , respectively.

Considering the whole situation after the main test, it can be said, that the working temperatures were slightly higher, than originally planned. Our estimate, based both, on the temperatures as found by OPTIX-readings, as well as on the behaviour of the material, calcined in the main test, when processed by selective hydration, indicates that the working temperatures varried betwsen 960°-1020°C, but prevailingly between 980°-1010°C.

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Table No. 12.

TECHNOLOGICAL DATA FOR MAIN CALCINING TEST

Data, Date	Designation	CM - 21 21.6.87	CM - 23 23.6.87	CM - 24 24.6.87	CM - 25 25.6.87	CM - 26 26.6.87	CM - 27 27.6.87	CM - 28 28.6.87	CM - 29 29.6.87	CM - 30 30.6.87	CM - 1 01.7.87	CM - 2 02/7/87	CM - 3 03.7.87	CM - 4 04.7.87
I. Shift	Feed, kg	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,440	4,800	4,800	4,800
	Prod.,kg	1,773	1,802	1,931	1,866	1,912	1,823	1,892	1,889	1,885	1,942	2,247	1,932	2,269
	Fuel, lit.	1,339	1,240	1,210	1,192	1,209	1,219	1,195	1,279	1,306	1,279	1,300	1,319	1,316
	Litre-Mass	-	-	-	1.17	1.10	1.11	1.11	1.12	1.21	1.13	1.17	1.19	1.02
II. Shift	Feed, kg	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,800	4,800	4,800	4,800
	Prod.,kg	1,907	1,890	1,952	1,916	1,877	1,947	1,873	1,908	1,906	2,268	2,283	2,296	2,246
	Fuel, lit.	1,333	1,268	1,233	1,190	1,182	1,212	1,188	1,303	1,288	1,301	1,338	1,340	1,285
	Litre-Mass	-	-	1.13	1.10	1.14	1.17	1.14	1.14	1.19	1.12	1.09	1.10	1.05
III. Shift	Feed, kg	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,080	4,800	4,800	4,800	4,800
	Prod.,kg	1,817	1,942	1,917	1,896	1,910	1,890	1,885	1,900	1,928	2,280	2,243	2,216	2,158
	Fuel, lit.	1,377	1,212	1,242	1,206	1,246	1,204	1,173	1,242	1,296	1,318	1,293	1,354	1,310
	Litre-Mass	-	-	1.08	1.13	1.20	1.14	1.01	1.18	1.14	1.10	1.12	1.07	1.12
Daily	Feed, kg	12,240	12,240	12,240	12,240	12,240	12,240	12,240	12,240	12,240	14,040	14,400	14,400	14,400
	Prod.,kg	5,497	5,634	5,800	5,678	5,699	5,660	5,650	5,697	5,719	6,490	6,773	6,444	6,673
	Fuel, lit.	4,049	3,720	3,685	3,588	3,637	3,635	3,556	3,824	3,890	3,898	3,931	4,013	3,911
	Litre-Mass	1.28	1.24	1.11	1.13	1.15	1.14	1.09	1.15	1.18	1.12	1.13	1.12	1.06
Cumulative	Feed, kg	12,240	24,480	36,720	48,960	61,200	73,440	85,680	97.920	110,160	124,200	138,600	153,000	167,400
	Prod.,kg	5,497	11,131	16,931	22,609	28,308	33,968	39,618	45,315	51,034	57,524	64,297	70,741	77,417
	Fuel, lit.	4,049	7,769	11,454	15,042	18,679	22,314	25,870	29,694	33,584	37,482	41,413	45,426	49,337
	Litre-Mass	1.28	1.26	1.21	1.19	1.18	1.18	1.16	1.16	1.16	1.16	1.16	1.16	1.15

Table No.13 .

SPECIFIC CONSUMPTION FIGURES
FOR THE MAIN CALCINING TEST
(For One Ton of Calcined Magnesite)

Input Data:

a)	Total Quantity of Raw Magnesite Consumed	- 167.4	t
b)	Total Quantity of Calcined Magnesite Produced	- 77.4	t
c)	Total Quantity of the Power Consumed	- 8147.o	kWh
d)	Total Quantity of Fuel Oil Consumed	- 49337.o	lt.
e)	Quantity of Calcined Magnesite Produced (when Feed = 4.8 t/Shift)	- 26.4	t
f)	Quantity of Fuel Oil Consumed (when Feed = 4.8 t/Shift)	- 15753.o	lt.
g)	Quantity of Calcined Magnesite Produced (when Feed = 4.1 t/Shift)	- 51.o	t
h)	Quantity of Fuel Oil Consumed (when Feed = 4.1 t/Shift)	- 33584.o	lt.

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SPECIFIC CONSUMPTION FIGURES:

A)	Raw Magnesite :	167.40	:	77.4	=	2.16	t
B)	Power:	8147	:	77.4	=	105.2	kWh
C)	Fuel Oil (Average)	49337	:	77.4	=	637.o	lt.
D)	Fuel Oil (4.8 t Feed)	15753	:	26.4	=	597.o	lt.
E)	Fuel Oil (4.1 t Feed)	33584	:	51.o	=	658.o	lt.

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Remark: lt. = litre

Table No. 14 .

Grain Size Distribution of the Calcined Magnesites from the Main Test - (Per Cent)

Sample	-25+15	-15+10	-10+5	-5+3	-3+1.2	- 1.2
CM 6-32/21	11.2	8.6	26.6	13.2	21.2	19.2
CM 5-25/23	10.5	10.3	29.5	15.8	18.5	15.4
CM 5-25/24	7.7	9.3	37.0	17.8	14.6	13.6
CM 5-25/25	4.6	6.1	30.2	18.3	21.4	19.4
CM 6-32/26	11.4	8.8	23.0	11.9	21.1	23.8
CM 6-32/27	9.7	5.6	24.4	16.6	23.8	19.9
CM 5-25/29	10.6	11.0	33.1	16.2	16.0	13.1
CM 5-25/30	7.5	6.2	28.7	23.2	18.2	16.2
CM 5-25/1	7.8	7.4	28.6	17.1	20.4	18.7
CM 5-25/2	12.5	7.8	32.5	15.4	18.1	13.6
CM 5-25/3	8.9	9.7	32.1	16.9	18.8	13.6
CM 5-25/4	7.0	7.9	29.6	17.9	21.4	16.2

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Table No. 15 .

Chemical Composition of the Calcined Materials from the Main Test - (Per Cent)

Sample	LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
CM 6-32/21	0.64	1.49			6.18	91.38
CM 5-25/23	0.84	1.22			5.77	91.86
CM 5-25/24	0.83	1.17			6.45	91.19
CM 5-25/25	0.64	1.37			6.03	91.65
CM 6-32/26	0.44	1.25			5.81	92.19
CM 6-32/27	0.95	1.15	0.11	0.17	6.17	91 .45
CM 5-25/29	0.42	1.10	0.10	0.23	6.32	91.83
CM 5-25/30	0.43	1.18			6.02	92.06
CM 5-25/1	0.51	1.48			7.10	90.60
CM 5-25/2	0.53	1.23			6.52	91.41
CM 5-25/3	0.56	1.14			6.06	91.93
CM 5-25/4	0.77	1.28			6.31	91.33
Average	0.63	1.26	0.1 1	0.20	6.23	91.57

C. Processing - Main Test

Calcined magnesite, split in quantities of daily productions, has been used for processing. So, the material processed from the calcined sample: CM 6-32/21 has got the designation: SP-21 , from the sample CM 5-25/23 the designation: SP-23, and so on.

The sample CM 6-32/27 represented the quantity produced in two days. Because of that, after the processing, this sample had been split in two parts, with the designation: SP-27 , and SP-28 , respectively.

Operational conditions for processing have been as follows:

- Unit batch: 50 kg of calcined magnesite,
- Water quantity for wetting:
  - a) for samples SP-21 through SP-29 - 5 wt. per cent
  - b) for samples SP-30 through SP-4 - 6 wt. per cent
- Duration of mixing (in concrete mixer): one minute
- Rotating speed of mixer: 24 rotations/minute,
- Soaking time: at least 24 hours,
- Screening on a double-deck vybrating screen with:
  - a) upper sieve: 3.4x3.4 mm,
  - b) lower sieve: 1.6x1.6 mm.

Because of the new set of sieves, the samples have been given new designations, as well, like:

- SP-21/A representing fraction: + 3 mm
- SP-21/B " " : + 1.6 - 3 mm
- SP-21/C " " : - 1.6 mm.

Semi-products, after being screened and weighed out, have been packed in plastic bags (50 kg net), and separately piled on wooden pallets. Quantities and recoveries of semi-products are given in the Table No. 16.

The specimens for chemical analyses have been prepared by collecting small quantities of the material from every second bag, after thorough mixing and quartering. The results from chemical analyses are given in the Table No. 17 , No. 18 , and No. 19 .

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Table No. 16 .

MAIN PROCESSING DATA

Quantities, Reactivities, and Recoveries of Semi-products

SP	Reactiv.	Semi-prod.A kg	%	Semi-prod.B kg	%	Product C kg	%	Total kg
21	45/100	1,313	30.5	1,334	31.0	1,660	38.5	4,307
23	75/105	1,725	30.7	1,575	28.1	2,316	41.3	5,616
24	105/110	1,048	28.8	978	27.0	1,609	44.2	3,635
25	108/120	2,100	33.1	1,775	28.0	2,462	38.9	6,337
26	56/78	1,311	30.5	1,152	26.8	1,835	42.7	4,298
27	81/112	1,257	30.0	1,157	27.6	1,780	42.4	4,194
28	94/112	1,345	28.6	1,294	27.5	2,065	43.9	4,704
29	84/111	1,862	34.3	1,559	28.8	2,000	36.9	5,421
30	73/116	2,567	36.7	1,855	26.6	2,568	36.7	6,990
1	74/102	1,936	35.3	1,542	27.4	2,102	37.3	5,630
2	82/108	2,071	33.5	1,707	27.6	2,406	38.9	6,184
3	96/121	2,019	32.3	1,762	28.2	2,464	39.5	6,245
4	117/126	1,817	33.8	1,400	26.1	2,130	40.1	5,361
Total		22.421		19,090		27,417		68,928
Average	84/109		32.5		27.7		39.8	

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Table No. 17

Chemical Composition of Semi-Products

Contents of Lime (Per cent)

Sample	SP-A	SP-B	SP-C
SP-21	3.59	4.37	8.70
SP-23	4.06	4,66	10.76
SP-24	3.38	4.26	9.52
SP-25	3.72	3.61	8.89
SP-26	3.66	5.61	8.27
SP-27	3.63	3.66	7.86
SP-28	3.55	3.45	6.34
SP-29	3.83	4.73	9.16
SP-30	3.75	4.47	11.95
SP-1	4.00	4.67	10.25
SP-2	3.73	4.40	8.87
SP-3	3.47	6.06	9.24
SP-4	3.37	6.36	9.26
Average	3.67	4.64	9.16

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Table No. 18 .

Chemical Composition of Semi-Products - Main Test
(Per cent)

Sample	LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
SP-A	5.94	1.21	0.11	0.20	3.67	88.87
SP-B	5.66	0.97	0.11	0.20	4.64	88.42
SP-C	7.66	1.01	0.11	0.20	9.16	81.86

Table No. 19 .

Real Chemical Composition of Semi-Products - Main Test
(Per cent)

Sample	LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
SP-A	0	1.29	0.12	0.21	3.90	94.48
SP-B	0	1.03	0.12	0.21	4.92	93.72
SP-C	0	1.09	0.12	0.22	9.92	88.65

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Table No. 20 .

Material Balance Sheet for Lime in Semi-Products

Input Data:

Sample / Per cent	SP-A	SP-B	SP-C
Recoveries	32.5	27.7	39.8
Lime Contents	3.67	4.64	9.16

QUANTITY OF LIME IN SEMI-PRODUCTS:

SP-A: 3.67 x 0.325 = 1.19 kg

SP-B: 4.64 x 0.277 = 1.29 kg

SP-C: 9.16 x 0.398 = 3.65 kg

Total Quantity of Lime 6.13 kg

Total Quantity of Lime in 100 kg of Calcined Magnesite = 6.23 kg

As it can be seen, Material Balance sheet for Lime in semi-products is in a good accordance with the Balance Sheet for Lime in the starting material, i.e. calcined magnesite.

Grain Size Distribution of Semi-Products is shown in the Table No. 21 .

Table No. 21 .

Grain Size Distribution of Semi-Products

Sample	+15	-15+10	-10+5	-5+3	-3+2.4	-2.4+1.7	-1.7+1.4	-1.4+1.2	-1.2+0.5	-0.5
SP-A	1.0	4.8	31.3	39.9	5.4	7.4	5.0	5.7	-	-
SP-B	-	-	-	12.6	18.6	35.4	22.1	[illegible]	5.7	-
SP-C	-	-	-	-	-	-	0.1	14.[illegible]	.9	53.7

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Mineralogical Investigations:

Mineralogical Compositions of semi-products "A", and "B", have been determined by means of X-Ray-Difractometer, and the results shown in the Fig. No. 10 , and No. 11 , respectively. The presence of following minerals has been registered: a) periclase, b) portlandite, and c) brucite. The peak at d = 2.33/2.34 stayed undefined.

Differential Thermal Analyses:

For the semi-products "A", and "B", the DTA-analyses have been done, and the corresponding diagram reproduced on the Fig. No. 12 . Two distinct peaks have been recorded: a) forst one, at 370°C, corresponding to the decomposition of $Mg(OH)_2$, and b) the second one, at 450°C, corresponding to the decomposition of $Ca(OH)_2$; intensity of $Ca(OH)_2$-peak is somewhat higher with the sample SP-B, having also a higher content of lime.

D. Additional processing of semi-products "A" and "B"

During sampling and packing of semi-products "A", and "B", it was found out, that the additional desintegration takes place. Carefull observations have confirmed, that in some brittle aggregates the binding material did not completely react , and held together smaller magnesite fragments. By additional mechanical treatment, the binding material desintegrated, releasing the pure magnesite fragments. In this way an additional quantity of lime could have been transferred in the fine fraction, increasing thus the purity of semi-products "A", and "B". In order to accelerate the desintegration of the mentioned aggregates, the obtained semi-products have been "tumbled" for one minute in the concrete mixer, and screened-out on the same screen set. Fot this tets the samples of 100 kg each have been taken from SP-25/A, and SP-25/B, and after the test given the designation: SP-25/AT, and SP-25/BT, respectively.

The second test, on a bigger scale, has been carried out with a sample SP-A, 2.2 t in weight, as well as with the sample SP-B, 1.2 t in weight. The summary of the results from all three mentioned tests have been given in the Table No. 22 for grain size distributions, and in the Table No. 23 for chemical compositions, respectively.

From the last two tables it can be seen, that by additional processing (tumbling and screening) of the semi-products "A", and "B", the possibility is attained to further reduce the lime content and obtain purer semi-products,

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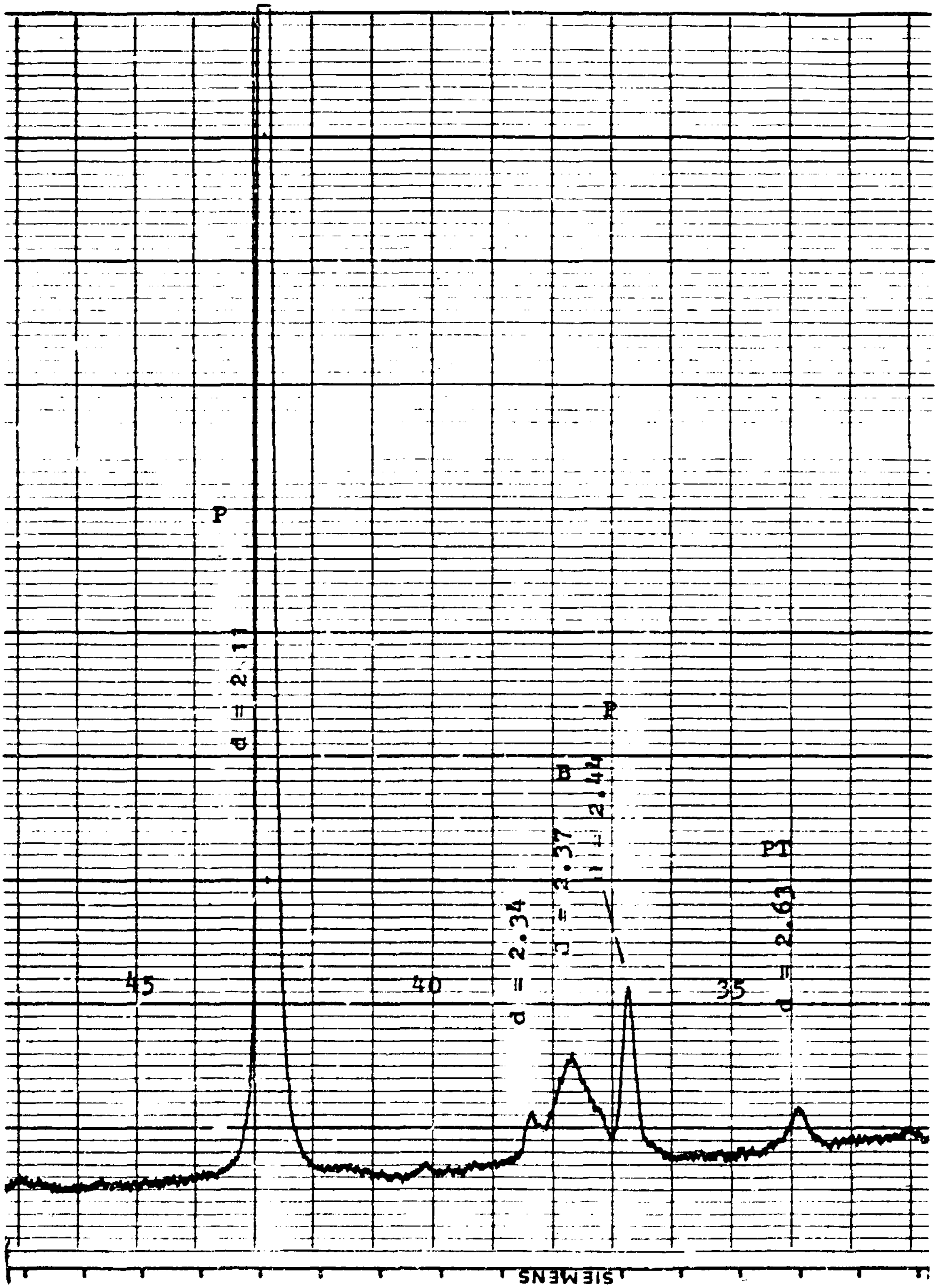

Figure No. 10 . X-Ray-Pattern: Sample SP-A

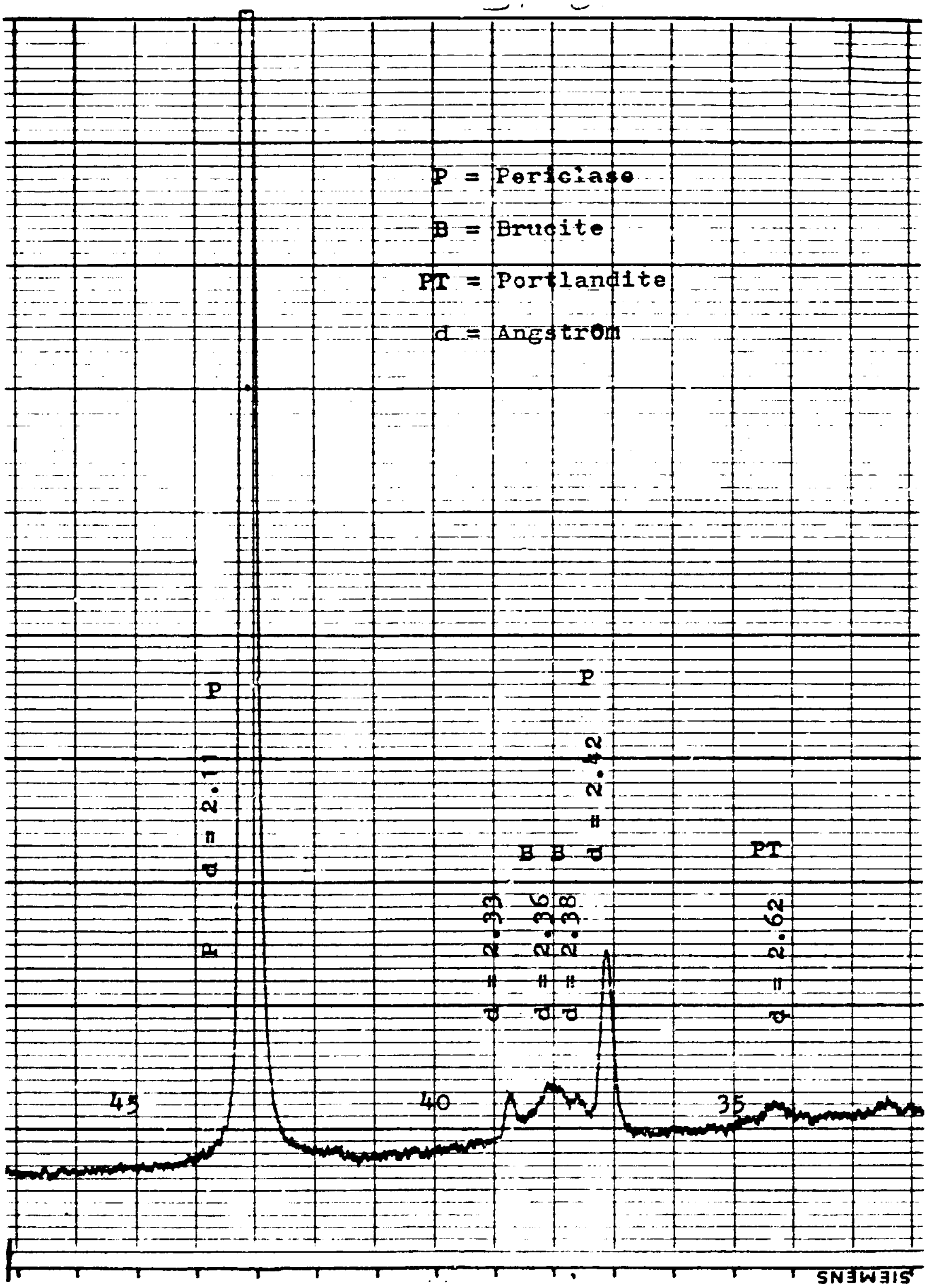

Fig. No. 11 . X-Ray-Pattern: Sample: SP-B

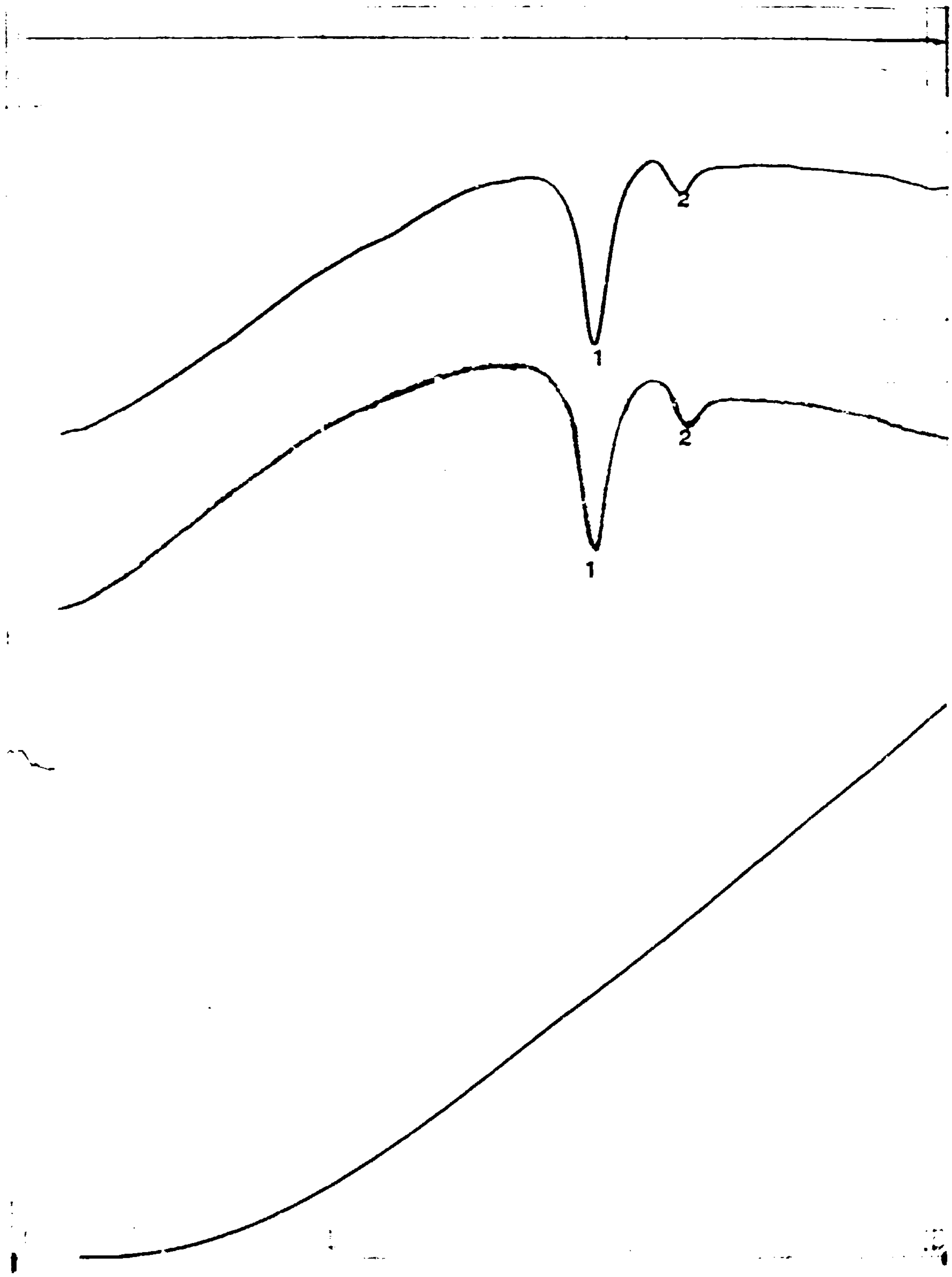

Fig. No. 12 .

DTA-Diagrams for Semi-products "A", and "B"

1) $Mg(OH)_2 \longrightarrow MgO + H_2O$

2) $Ca(OH)_2 \longrightarrow CaO + H_2O$

SP-AT, and SP-BT. Naturally, on the account of recoveries. It is obvious, that in this way, the process of up-grading of raw magnesite by selective hydration becomes more flexible. However, this should be confirmed by a test with larger quantities.

Table No. 22 .

Grain Size Distribution of Semi-products after Additional Processing

Sample	+ 15	-15+10	-10+5	-5+3	-3+2.4	-2.4+1.7	-1.7+1.4	-1.4+1.2	-1.2+0.5	-0.5
SP-AT	2.4	4.9	31.3	55.6	5.8					
SP-BT	-	-	-	6.3	25.0	40.7	22.1	4.1	1.8	-
SP-CT	-	-	-	-	-	-	3.7	16.7	41.4	38.2

Table No. 23 .

Chemical Composition of Semi-products after Additional Processing (Per cent)

Sample	LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
SP-AT	5.64	1.24	0.11	0.20	3.34	89.47
Real Content	-	1.31	0.12	0.21	3.54	94.78
SP-BT	5.50	0.82	0.11	0.20	3.46	89.91
Real Content	-	0.87	0.12	0.21	3.66	95.14
SP-CT	8.67	1.33	0.11	0.20	8.02	81.67
Real Content	-	1.46	0.12	0.22	8.78	89.45

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Recoveries of semi-products from the main test have been given in the Table No. 24 , and the recoveries of semi-products, obtained after the additional processing, in the Table No. 25 . In both cases the percentage of recoveries have been calculated from the quantity of the calcined magnesite, used for the beneficiation process by selective hydration.

Table No. 24 .

Recoveries of Semi-products from the Main Test
(Per cent)

Semi-product	Recovery
SP-A	32.5
SP-B	27.7
SP-C	39.8

Table No. 25 .

Recoveries of Semi-products from Additional Processing
(Per cent)

Semi-product	Recovery
SP-AT	20.2
SP-BT	29.5
SP-CT	50.3

By additional processing (tumbling + screening) of semi-products SP-A, and SP-B, the semi-products SP-AT, and SP-BT with better and almost the same chemical compositions have been obtained. With only one additional treatment a considerable improvement of the quality of semi-product "B"

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has been achieved, so that both SP-AT, and SP-BT become practically one and the same semi-product, with the recovery of up to 50 per cent. This recovery is a very good one, especially for this breccia raw magnesite with high lime content.

E. Evaluation of the results from the Main Test

For the main test raw magnesite has been screened out on a sieve with appertures: 5x5 mm, in order to avoid unnecessary burden for the calcining process , by utilizing of the fine fractions, the quality of which cannot be improved by this method. The screened material has been given the designation: RM 5-25 (mm). The content of the particles below 5 mm, remaining after the screening , has been brought up to about 5 per cent. This represented noticeable improvement against the sizing in the trial test. In oder to check the influence of the coarser sizing of raw magnesite on the grain size distribution of calcined material, raw magnesite having the sizing 6-32 mm, RM 6-32 , has been used as well.

Macroscopic appearance of the calcined magnesite, CM 6-32/21, produced from RM 6-32, confirmed that it had reached slightly higher degree of densification, indicating thus somewhat higher working temperature, as well. Daily production of calcined magnesite, CM 5-25/23, was contaminated by the pieces of the refractory lining's coating, caused by the shut-down of the rotary kiln in the meantime (due to repair of the main exhaust fan). All other daily lots have had uniform macroscopic appearance, with particles white in colour, and well developed internal cracks. On the basis of this, the impression of the material being a litle bit "harder" calcined has been got. The last day production , CM 5-25/4, seemed to be "softer" (i.e. calcined at slightly lower temperatures).

Calcined material from the main test has had better grain size distribution, than the ones from the trial tests. Also, the material obtained by calcining of the RM 5-25, has shown better grain size distribution (lower content of particles below 3 mm, and below 1.2 mm, respectively), than the material out of RM 6-32.

Litre-Mass-values for daily productions of calcined materials varried between 1.06 and 1.28 kg/litre. With the CM 6-32/21 , and CM 5-25/23 these values were higher than wanted to (1.0 to 1.2 kg/litre). All other

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daily productions have had the litre-mass in the same range, but prevailingly above 1.10 kg/litre.

In respect of chemical composition it should be stated, that all daily lots have had the loss-on-ignition-values below 1 per cent, average being 0.63 per cent. The average lime content of the calcined magnesites has been 6.23 per cent.

The reactivity values of the material have been as follows:

- after 1 hour : 45 - 117°C ; average 84°C
- after 2 hours : 78 - 126°C ; average 109°C .

Some relation between the reactivity, and the calcining grade has been found for the temperatures, taken after 1 hour; the temperatures taken after 2 hours were, more or less, at the same level. The only exceptions were the reactivities for the material calcined above 1000°C.

Considering the results from the trial tests, it would have been necessary to change the set of wire sieves. Unfortunately, it was not possible to follow this finding, due to the fact that the availability of the sieves was pretty limited. So, instead of having the upper sieve with standard appertures: 3.15x3.15 mm, the sieve from the trial test had to be used (appertures: 3.4x3.4 mm). And, the lower sieve, instead of having appertures: 1.4x1.4 mm, had to be replaced by a sieve, having appertures: 1.6x1.6 mm. Because of that, the recovery of semi-product SP-B was smaller, but, on the other side, its quality improved.

With the mentioned set of sieves, following average recoveries of semi-products has been achieved:

- for SP-A 32.5 wt. per cent
- for SP-B 27.7 wt. per cent, and
- for SP-C 39.8 wt. per cent.

The obtained values differed pretty much from those, obtained in the trial tests, especially for SP-B, and SP-C, respectively.

Wetting of the calcined material for the first 8 daily lots has been done by 5 wt. per cent of water. However, due to the fact that the calcining has been carried out at a somewhat higher working temperature, it was increased up to 6 wt. per cent, in order to reach slightly higher reactivity, being that the soaking time had to be limited at max. 24 hours (tight programme of work). The material, properly calcined, would have not needed

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more than 5 wt. per cent of water.

The average lime contents of the produced semi-products, have been as follows:

- for SP - A 3.67 per cent
- for SP - B 4.64 per cent, and
- for SP - C 9.16 per cent.

Because of being slightly "harder" calcined SP-A has shown a little bit higher lime content, than in the trial test. Lime content in SP-B has been somewhat lower, due to bigger appertures (1.6x1.6 mm) of the lower sieve.

By additional processing of the semi-products SP-A, and SP-B, (tubling + screening) new semi-products have been obtained, having the lime content as follows:

- SP-AT 3.34 per cent, and
- SP-BT 3.46 per cent.

The fact of outstanding importance, found out during semi-industrial investigations, is that even the semi-product "C" represents a valuable, salable product. In this way both, the technological and economical viability of the developed beneficiating process has been considerably improved.

The properties of semi-product "C", which have been given in the Table No. 26 , can be used for investigating the possibility of its placement on both, domestic and foreign (SADCC-, and PTA-) markets.

Table No. 26 .

Properties of Semi-product SP-C

a). Macroscopic appearance: white, loose, and sodt powdered material;

b). Chemical composition: (in per cent):

		Typical
LOI	6 - 9	7.5
SiO_2	0.6 - 2	1.3
Al_2O_3	0.1 - 0.3	0.15
Fe_2O_3	0.2 - 0.4	0.3
CaO	7 - 11	9.0
MgO	77 - 86	81.5

c) Sizing: 0 - 1.4 mm; typical: + 1.4 mm 0 - 5 %; -1.4+1.2 mm 10-15 %; -1.2+0.5 mm 30-40; -0.5+0.1 30 - 40; -0.1 10-15 %.

d), Litre-Mass: 1.15 - 1.25 kg/litre.

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e). Mineralogical Composition:
Main mineral: Periclase - MgO
Accompanying minerals: Portlandite - $Ca(OH)_2$, and Brucite - $Mg(OH)$.

VI. OTHER RAW MATERIALS

A. Collecting of the Representative Samples

In the II. phase of semi-industrial investigations, to be carried out in Europe, following should be done: (details are given in the Annex No. 12):

- To produce two qualities of dead-burned magnesite, i.e.: DB-A (better quality), and DB-B;
- To produce out of DB-A dead-burned magnesite following test bricks:
  - a) Magnesite Bricks,
  - b) Magnesia-Carbon Bricks, and
  - c) Magnesite-Chrome Bricks

  using local flake graphite, and chrome-ore concentrates.

For the realization of the planned II. phase of semi-industrial investigations following representative samples have been collected:

Flake Graphite:

Representativa sample of flake graphite "A-15", packed in plastic bags, 50 kg each, has been taken from the regular production of the LYNX-mine, according to the Annex No. 13 .

Chrome ore concentrates:

Two representativa samples, 2.o t each, of following concentrates from Mtoroshanga chrome ore mine, have been taken at random from the existing stock-piles, i.e.:

- a) D-20, with grain sizes between 0.5 and 3.o mm, having about 55 per cent of Cr_2O_3 , and max. 1.5 per cent of silica, and
- b) D-26, with grain sizes betwee 0 and 1.o mm, having the same characteristics, as the sample D-20.

These samples have been separately packed in the plastic bags, 50 kg each, and transferred to the Department of Metallurgy, Harare.

During the visit, paid to the FRANCES-mine of lumpy chrome ore, it has

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been found out, that it has been closed, the most important sold, and the mine itself overflooded. Because of that, no representative samples of lumpy chrome ore could have been taken. It will be replaced by chrome-ore concentrate, D-20.

All collected representative samples have been stocked, and will be kept by the Department of Metallurgy, Harare.

VII. MARKET STUDY

Due to the fact that the Zimbabwean Government intends to include the high alumina refractories in the production programme of the future plant, and due to the fact that the semi-product "C" represents a valuable, salable product, it would be one of the first priorities to soonest possibly star to collect the informations on the present (1990), and future (2000)-demands of:

- All kinds of basic refractories (magnesite-, magnesite-chrome-, chrome-magnesite, magnesia-carbon-bricks, mortars, specialty mixes, masses, etc.);
- All kinds of high alumina refractories, and
- Caustic calcined magnesite (semi-product "C").

The best way to go in this connection would be: to contact all bigger users of the mentioned materials (consuming one hundred and more tons), to interview their refractory specialists, and to collect all relevant data according to the Annex No. 19, attached to the Report (2).

It might be useful to start already now the negotiations with friendly countries, which are bigger consumers of refractories, and of caustic calcined magnesite (as, for instance: Zambia), asking them to consider the possibility of their financial participation in the establishment of the refractories plant in Zimbabwe.

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Basic refractory bricks, which will be needed by potential Zimbabwean and foreign consumers - according to the available informations, could be as follows:

- for steel industry: magnesite-, magnesite-chrome-, and magnesia-carbon bricks;
- for cement industry: magnesite-chrome bricks,
- for ferro-alloys: magnesite-, and magnesite-chrome bricks,

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- for non ferrous metallurgy: magnesite-chrome bricks,
- for ceramic industry: magnesite-, and magnesite-chrome bricks, and
- corresponding quantities of accompanying mortars, specialty masses, mixes, and repairing materials for the existing kilns, furnaces, etc.

In any case, an exact answer on this very important question, what should be the capacity, and the production programme of the future plant, can only be obtained from the accurate market analysis, which should be attached to the feasibility study.

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As to the caustic calcined magnesite, semi-product "C", major industrial applications include the following (5):

- Fertilizer industry - as important additive;
- Pulp and paper industry - for the preparation of the sulfite lye used in the "magnefite" papermaking process;
- Rubber industry - magnesia is particularly effective in controlling vulcanisation and currig in neprene rubbers and other elastomers;
- Plastics, paints, adhesives - as flame retardant filler;
- Abbrasives - as a binder in grinding wheels;
- Lubricating oils - as an additive to reduce the emmission of sulphur and other polutants;
- Flue gas desulphurization - again to remove sulphur;
- Flux in steel making - normally used when magnesia is more readily available than dolime or olivine;
- Chemicals - when magnesia is a starting material for the production of other magnesium salts, such as sulphate, nitrate, etc.;
- Pharmaceuticals - special grades of oxide, hydroxide, and carbonate are used in antacids, cosmethics, toothpaste, ointments, milk of magnesia, etc.;
- Steel coatings - to coat grain orientated silicon steel used in electrical transformer cores;
- Fused magnesia - caustic magnesia as a raw material for fused magnesia.

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VIII. SUMMARY OF FINDINGS AND RECOMMANDATIONS

A. Findings

1. Properties of raw magnesite from Kadoma mine, which is exploited at present, and which has been used for semi-industrial investigations, are almost identical with the properties of the ore, which has been used for laboratory scale tests (1984/1985). The only one difference is the presence of small quantities of calcite, not registered earlier. Average content of lime in the ore was 3.03 wt. per cent, as used in these investigations.

2. Calcined magnesites, as produced in the trial tests, have had somewhat finer sizing, good chemical composition (average lime content = 6.21 wt. per cent), and good mineralogical composition. Being without residual carbonates, and having good reactivity, they enabled the production of up-graded semi-products "A", and "B", of good quality. Calcined magnesites from the main test have had better grain size distribution, good chemical composition (average lime content = 6.23 wt. per cent), and good mineralogical compositions. Due to unsufficient sensitivity of optical pyrometer, they have been slightly higher, "harder", calcined, at the working temperatures of 960-1020°C, prevailingly between 980-1010°C.

3. Both, the trial tests, as well as the main test have shown that working temperature during calcining is the most influencing factor for the properties of calcined magnesite, if it should be up-graded by selective hydration method. On the basis of the results of these semi-industrial investigations, the optimal working temperature for calcining of Kadoma raw magnesite in the rotary kiln should be: $950 \pm 20°C$.

4. An useful quick practical method for the first control of the quality of calcined magnesite - measuring the litre-mass at the kiln site - has been developed. It has been found out, that the litre-mass values of the properly calcined magnesite for this purpose, vary between 1.0 and 1.15 kg/litre.

5. During the main calcining test about 77 t of calcined magnesite have been produced, with the following specific consumption figures per 1 (one) ton of calcined material:

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- Raw magnesite	2.16	t
- Fuel oil	597	litre
- Power	105.2	kWh

Specific consumption figure of 2.16 t of raw magnesite for one ton of calcined material represents a very high grade of utilization of the ore. In practice this figure varies between 2.2 and 2.6 t, depending on the type of the ore, on one side, and on the calcining operational conditions, on the other.

Very high consumption figure for fuel oil has been caused by:
- the lack of heat recuperation system with the rotary kiln, used for calcining of magnesite;
- rotary kiln being to short, partly water cooled (kiln entrance has been without refractory lining);
- very powerful exaust fan (taking to much heat out of the kiln);
- very high temperature of the calcined material, when leaving the rotary kiln;
- cold secondary air, etc., etc.

Modern, very efficient kilns for calcining of magnesite, depending on its capacity, and on the properties of the ore in question, would consume:

- Shaft kiln:	100-120 litre of fuel oil
- Rotary kiln	160-200 litre of fuel oil.

6. From the best trial processing tests, semi-product "A" contained 3.26 wt. per cent of lime (corresponding to 3.45 per cent of the real lime content).

7. During the mein test following quantities of semi-products have been obtained:

- SP - A	22.4 t
- SP - B	19.1 t
- SP - C	27.4 t

Following average recoveries of semi-products have been achieved:

- SP - A	32.5 per cent
- SP - B	27.7 " "
- SP - C	39.8 " "

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8. Chemical compositions and recoveries of semi-products, as obtained from trial tests, main test, and from additional processing, respectively, have been given in the Table No. 27 .

Table No. 27 .

Chemical Compositions and Recoveries of Semi-products

A. Obtained from Trial Tests:

Semi-product	LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Recovery
SP - A	5.63	1.13	0.11	0.20	3.26	89.67	30.26
Real Content	0	1.20	0.12	0.21	3.45	95.02	
SP - B	6.24	1.14	0.11	0.20	4.85	87.46	39.50
Real Content	0	1.22	0.12	0.21	5.17	93.24	
SP - C	7.79	1.37	0.11	0.20	11.27	79.26	30.24
Real Content	0	1.48	0.12	0.21	12.22	85.96	

B. Obtained from Main Test:

SP - A	5.94	1.21	0.11	0.20	3.67	88.87	32.50
Real Content	0	1.29	0.12	0.21	3.90	94.48	
SP - B	5.66	0.97	0.11	0.20	4.64	88.42	27.70
Real Content	0	1.03	0.12	0.21	4.92	93.72	
SP - C	7.66	1.01	0.11	0.20	9.16	81.86	39.80
Real Content	0	1.09	0.12	0.22	9.92	88.65	

C. Obtained from Additional Processing (Tumbling + Screening):

SP - AT	5.64	1.24	0.11	0.20	3.34	89.47	35.55
Real Content	0	1.31	0.12	0.21	3.54	94.78	
SP - BT	5.50	0.82	0.11	0.20	3.46	89.91	48.92
Real Content	0	0.87	0.12	0.21	3.66	95.14	
SP - CT	8.67	1.33	0.11	0.20	8.02	81.67	17.56
Real Content	0	1.46	0.12	0.22	8.78	89.45	

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The results of the recoveries, lime contents, and lime reductions, as achieved in trial tests, main test, and additional processing, respectively, have been shown in the Table No. 28 .

Table No. 28 .

Recoveries, Lime Contents and Lime Reductions

A. Achieved in Trial Tests (in per cent):

Semi-product	Recovery	Lime Contents Before	After	Lime Reduction (Per cent)
SP - A	30.26	6.21	3.45	44.44
SP - B	39.50	6.21	5.17	16.75

B. Achieved in Main Test:

SP - A	32.50	6.23	3.90	37.40
SP - B	27.70	6.23	4.92	20.03

C) Achieved by Additional Processing (Tumbling + Screening):

SP - AT	20.	6.23	3.54	43.18
SP - BT	29.45	6.23	3.66	41.25

In the course of the trial tests already the lime reduction by 44.44 per cent with the semi-product "A" (sizing: -15+3 mm) has been achieved. However, with the semi-product "B" (sizing:-3+1.2 mm) only the lime reduction of 16.75 per cent has been achieved, because of to small appertures (1.2x1.2 mm) of the used sieve.

In the course of the main test, during which slightly "harder" material has been obtained, somewhat lower lime reduction - 37.40 per cent - with the semi-product "A" has been achieved. As to the semi-product "B", slightly higher lime reduction - 20.03 per cent - due to bigger appertures of the lower sieve (1.6x1.6 mm), has been achieved.

By additional processing of semi-products "A", and "B", their lime content has been further reduced. This has especcially been the case with semi-product "B". After this simple technological operation following lime reduction percentage have been achieved:

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- with SP - AT 43.18 per cent, and
- with SP - BT 41.25 per cent.

In this way semi-product "B" has been transferred in the group of highest quality grade, to which also semi-product "A" belongs.

The results obtained from semi-industrial investigations have confirmed, that the up-grading of Kadoma raw magnesite has been successfully solved, and that the selective hydration process has enabled to obtain semi-products, out of which the dead-burned magnesite, DBM-A, can be produced, having following chemical composition:

SiO_2	1.0 - 1.5 per cent
Al_2O_3	0.1 - 0.15 " "
Fe_2O_3	0.15- 0.25 " "
CaO	3 - 4 " "
MgO	94.2 - 95.5 " "

with the recovery of up to 50 per cent, calculated from the starting calcined material, which is used for selective hydration process.

In addition to the main dead-burned magnesite, DBM-A, three additional grades of dead-burned magnesites could be produced, if the real demand for them on the market would exist, i.e.:

- DBM-B from the semi-product "B" ,
- DBM-BS (stabilized sinter), from the semi-product SP-B with additives, and
- DBM-D, lowest and cheapest grade of dead burned magnesite for the production of ramming and gunning mixes - produced by direct dead-burning of raw magnesite RM 5-25, without any additives,

with chemical compositions as given hereunder:

	DBM-B	DBM-BS	DBM-D
SiO_2	1.0 - 1.5	2.0 - 2.2	1.0 - 1.5
Al_2O_3	0.12	0.2	0.12
Fe_2O_3	0.21	0.5	0.21
CaO	4.5 - 5.0	4.5 - 5.0	6.0 - 8.0
MgO	93 - 94	92 - 93	90 - 92.5

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9. Of outstanding importance is the fact, found out during semi-industrial investigations, that even the semi-product "C" represents a valuable, salable product, what is considerably improving both, the technological, and economical viability of the developed process.

10. On the basis of the results, obtained from semi-industrial investgations, it is possible to define operational conditions for the upgrading of raw magnesite from Kadoma-mine by selective hydration method, as follows: (Block diagram in the Fig. No. 13):

a) Raw Magnesite:

- Sizing:	5 - 25 mm
- Silica Content:	up to 1.0 per cent
- Lime Content:	up to 4.0 per cent

b) Calcining:

- Equipment:	a modern rotary kiln with recuperative system and cooler
- Kiln Feed:	to be adjusted according to the kiln capacity
- Working temperature	950° ± 20°C
- Properties of calcined magnesite:	
- Sizing:	0 - 25 mm
- Loss-on-ignition:	max. 1.0 per cent
- SiO_2	max. 2.0 per cent
- CaO	max. 8.0 per cent
- Litre-Mass:	1.0 - 1.15 kg/litre
- Stock-piling of calcined magnesite:	in concrete bunkers with steel plate lining (7 days)

c) Processing of calcined magnesite (from the stock-pile):

- Equipment:	Drum mixer, 25 r/min., or similar
- Wetting:	5 wt. per cent of water
- Mixing time:	one minute
- Unloading of drum-mixer:	in zinc-plated or stainless steel containers, covered by detachable lid
- Capacity of containers:	500-1000 litres
- Soaking time in containers:	min. 24 hours
- Stock-piling of hydrated material:	in concrete silos, or bunkers
- Screening equipment:	double-deck vybrating screen, adjusted to plant capacity, dedusted

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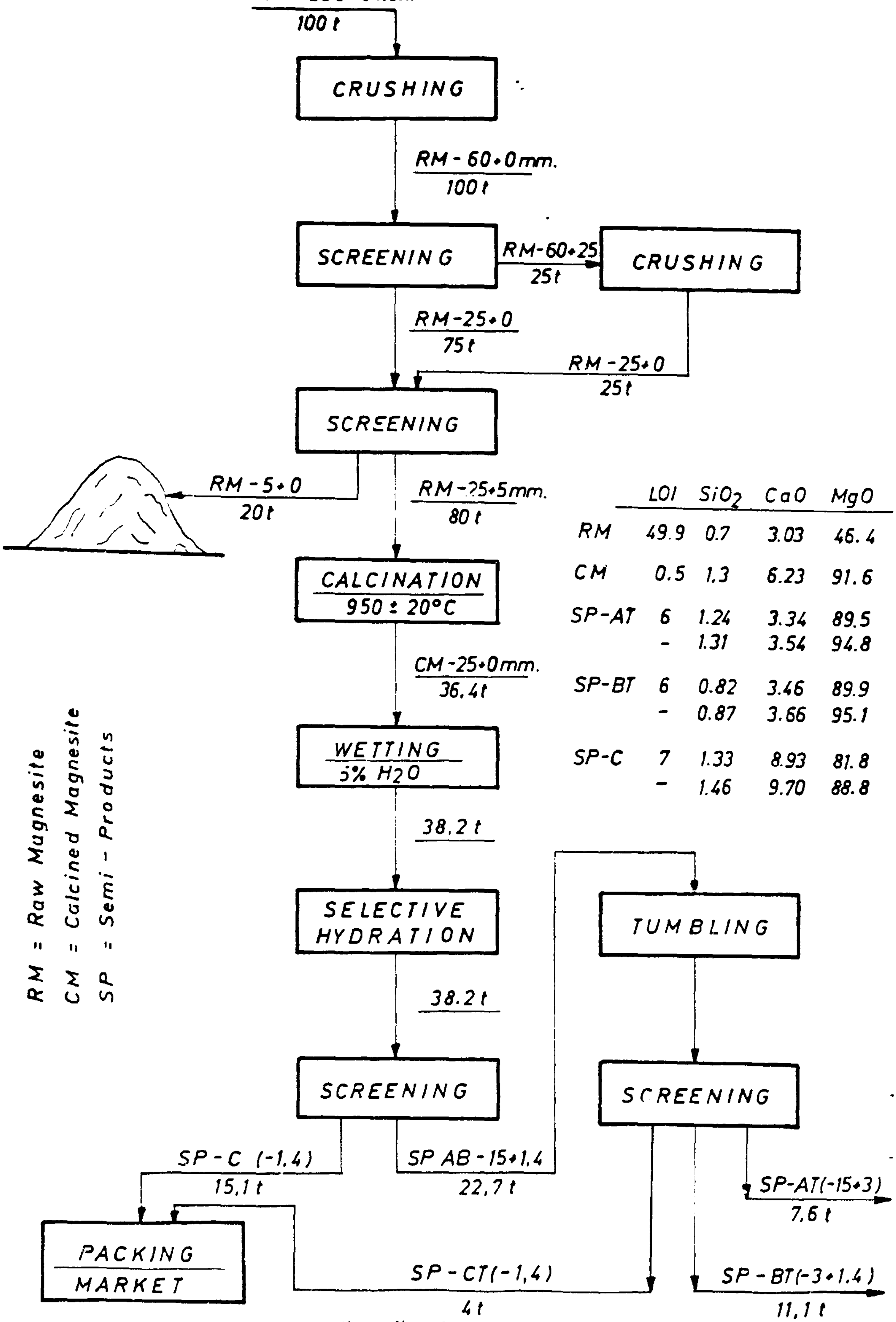

	LOI	SiO_2	CaO	MgO
RM	49.9	0.7	3.03	46.4
CM	0.5	1.3	6.23	91.6
SP-AT	6	1.24	3.34	89.5
	-	1.31	3.54	94.8
SP-BT	6	0.82	3.46	89.9
	-	0.87	3.66	95.1
SP-C	7	1.33	8.93	81.8
	-	1.46	9.70	88.8

Fig. No. 13 .

BLOCK DIAGRAM
SELECTIVE HYDRATION PROCESS

- Wire sieves: upper position: 3.15x3.15 mm (to be adjusted if necessary)
  lower position: 1.4x1.4 mm (to be adjusted if necessary)

d) Additional Processing:

- Tumbling Equipment: Drum mixer, as above
- Screening Equipment: Vybrating screen, as above

e) Final products:

- Semi-product "A" SP - A
- Semi-product "B" SP - B
- Semi-product "C" SP - C
- Semi-product "AT" SP - AT
- Semi-product "BT" SP - BT
- Semi-product "CT" SP - CT

Chemical Compositions and Recoveries of Final products have been given in the Table No. 27 , page 68 .

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B. Recommandations

1. It is recommanded that the second phase of semi-industrial investigations with about 20 t of semi-product "A", and about 6 t of semi-product "B" , be carried out in Yugoslavia/EUROPE as soon as possible, according to the proposed Programme of Work, which is attached to this Report as the Annex No. .

2. If the second phase of semi-industrial investigations prooves to be successful, it is recomanded to prepare the feasibility study for the complete project.

3. It is recommanded to further explore the market in SADCC-, and PTA-countries for:

   a) All types of basic refractories,
   b) All types of high alumina refractories, and
   c) Caustic calcined magnesite (Semi-product "C").

   In order to ensure quite relyable informations it is recommanded to collect them by direct interviewing of all bigger potential consumers, enabling the preparation of a very pricise MARKETING STUDY, on the basis of which it can be decided on:

   i) the assortment (qualita and shapes) of the bricks to be produced, and
   ii) the total capacity of the potential refractory plant

   for all final products mentioned above.

4. It is recommanded that the GEOLOGICAL SURVEY, Harare, soonest possibly starts the work, which will ensure that the quality and available reserves for Kadoma magnesite, lumpy chrome ore (FRANCES mine), and chrome ore concentrates (Mtoroshanga mine), will be properly confirmed.

5. It is recommanded that the additions of the existing staff at the Department of Metallurgy, Harare, soones possibly be employed, enabling them to specialise in the fields of ceramics and refractories.

6. It is recommanded to equipp the Ceramic Department of the Department of Metallurgy, Harare, with:

   i) Apparatus for determination of Cold-Crushing Strength;
   ii) Apparatus for determination of the Refractoriness, and

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iii) Apparatus for determination of Refractoriness-under-Load.

In this way the Department of Metallurgy, Harare, would be enabled both: a) to carry out comprehensive investigations in the fields of ceramics and refractories, and b) to further educate and train the skilled staff necessary for future industrial development of Zimbabwe, and for better utilization of huge reserves of non-metallic minerals in this country.

7. It is recommanded to carry out the investigations on the viability of local raw materials for the production of high alumina bricks, being that Zimbabwe disposes of substantial deposits of kyanite, sillimanite, corrundum, bauxite, flint clay, etc.

8. It is recommanded to provide the most important scientific literature (books, journals, etc.) for the fields of ceramics and refractories, in order to enable the staff to get additional knowledge, as well as acquintance with the newest development in these fields.

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ANNEX No. 1.

PROGRAMME OF WORK
(DP/ZIM/83/006)

A. Travels (Belgrade - Vienna - Harare - Vienna - Belgrade)
Briefing and debriefing in Vienna - One week

1.
- Inspections of Kadoma Mine and of rotary kiln.
- Preparatory meetings
- Discussions on Programme of Work and determining its extent and the time schedules.
- Collecting of Raw Magnesite Representative Samples for Trial Tests:
  a) 50-55 t 3-25 mm at Railway site
  b) 17-20 t 25-60 mm
  c) 12-15 t 3-60 mm
     (prepared from: 75 wt. % of a), and
     25 wt. % of b).
- Determination of Properties:
  i) Grain Size
  ii) Chemical Composition
  iii) Physical Properties
  iv) Mineralogical Composition
  v) DTA/TGA
  vi) Distribution of Contaminants by Electrom-Micro-Probe (only on the sample 3 -60 mm)
- Evaluation of Results

Duty Station: Kadoma
Dead Line: 12.05.1987 (excluding distribution of contaminants).

2. <u>First Check of the rotary kiln</u> :

- Mechanical Repair of the kiln, including all equipments connected to it ;
- Relining of the kiln-entrance with ramming mix ;
- Cleaning up of the kiln area ;
- Preparing of Representative Samples of Raw Magnesite (stock-piled at Eiffel Flats) ;
- Check of the rotary kiln in cold state ;

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- Ensure the even feed of rotary kiln (belt conveyor, wheel-barrows, scale, etc.) ;
- Ensure sufficient quantity of fuel oil (with its characteristics) ;
- Heat up the kiln when additional lining is ready ;
- Due to the fact that the old lining contains infiltrates and a coating, clean it up by sufficient quantity of raw magnesite 3-25 mm ;
- Check the number of revolutions per minute, as well as the possibility of reaching the working temperature of up to 1200°C, and take notice of the necessary time period ;
- Find out what are the approximate hourly capacities of the kiln, when calcining raw magnesite at :
  - a) 900°C
  - b) 1000°C
  - c) 1100°C
- Find out the avarage consumption figure for fueloil (per hour) for working temperatures between 1000°C and 1100°C.

Duty Station : Kadoma

Dead line : 12.05.1987.

3. <u>Prelininary Calcining Test</u> :

- For these tests the following raw magnesite classes : a) 3-25 mm ; b) 25-60 mm, and c) 3-60 mm shall be used and calcined at the working temperatures of 900°C , 1000°C, and 1100°C .

The approximate quantity of each class shall be 12 t .

Duty Station : Kadoma

Dead Line : 20.05.1987 .

4. <u>Determinations of the properties of calcined magnesites</u> (9 samples) :

- Grain Size
- Chemical Composition
- Physical Properties
- Reactivity

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- X-Ray-Pattern
- DTA/TGA
- Evaluation of the results .

Duty Station : Kadoma/Harare
Dead Line : 28.05.1987.

5. Selective Hydration of 9 Samples of Calcined Magnesites

- Determination of properties of 9 x 3 = 27 samples of Semi-Products ("A", and "B") :
  - Grain Size
  - Chemical Composition
  - Physical Properties
  - X-Ray Pattern
  - DTA/TGA
- Evaluation of the Results
- Defining the optimum Conditions for the main test.

Duty Station : Kadoma
Dead Line : 20.06.1987.

6. MAIN TEST - Representative Sample

- Collecting of a new representative sample of 150 t according to the results of the preliminary tests.
- Determination of the properties :
  - Grain Size
  - Chemical Composition
  - Physical Properties
  - DTA/TGA
- Evaluation of the Results.

Duty Station : Kadoma
Dead Line : 26.06.1987.

7. Main Calcining Test (150 t) :

- Heating up of the Rotary Kiln
- Production of approximately 60 t of calcined magnesite
- Process Control (every 8-hour shift) :
  - Grain Size of Calcined magnesite
  - Chemical composition of calcined magnesite
  - Reactivity
- Daily Process Control :

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- Grain Size (1 Sample)
- Chemical Composition (1 Sample)
- Reactivity (1 Sample)
- Physical Properties (1 Sample)
  a) X-Ray Pattern
  b) DTA/TGA

- Establishing of specific consumption figures for Raw Magnesite, Fuel Oil, and Power.

Duty Station : Kadoma
Dead Line : 10.07.1987.

8. Selective Hydration - Main Test :

- Determination of the Properties of Representative Sample (60 t) of Calcined Magnesite :
  - Grain Size
  - Chemical Composition
  - Reactivity
  - Physical Properties
  - X-Ray-Pattern
  - DTA/TGA
- Production of approximately 22 tons of Semi-Product "A"
- Production of approximately 18 tons of Semi-Product "B"
- Determination of Properties of Semi-Products "A" and "B";
  - Grain Size
  - Chemical Compbsition
  - Physycal Properties
  - X-Ray-Pattern
  - DTA/TGA
- Establishing of Recovery of Semi-Products "A" and "B"
- Evaluation of the Results.

Duty Station : Kadoma/Harare
Dead Line : 01.08.1987.

9. Collecting of Representative Samples of :

- Lumpy Chrome Ore (Francies Mine), 50-200 mm - 2 t
- Chrome Ore Concentrates (Mtoroshanga) :
  - "D-20" - 2 tons
  - "D-26" - 2 tons
- Flaked Graphite - 0.75 tons

This will be carried out at appropriate time during the programme ./.

10. Preparation of ... Terminal Report with Conclusions and Recommandations

- Writing and Typing of Master Pages
- Reproduction of all Photographs and Diagramms
- Reprinting (10 copies)
- Completing, binding, etc.

Duty Station : Harare
Dead Line : 18.08.1987

11. Indicated Dead Lines in the Programme of Work willbe subject to alteration depending on circumstances agreed to by the partners.

To this Programme of Work the List of all the determinations, to be carried out, and the delivery terms of relevant corresponding reports is attached.

Signed this day of 30th April, 1987.

FOR MINISTRY OF MINES	UNIDO EXPERTS
C. Ushewokunze,	J. Vlajcic
Permanent Secretary	I. Budimir

ATTACHEMENT TO THE PROGRAMME OF WORK
(DP/ZIM/83/006)

Determinations to be carried out :

1) Chemical Analyses of $MgCO_3$:
 a) Ingredients: LOI, SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO (2 days)
 b) " : LOI, SiO_2, CaO - (2 days), up to 7 samples

2) Chemical Analyses of Calcined MgO :
 a) LOI, SiO_2, Al_2O_3, Fe_2O_3, CaO and MgO - (2 days)
 b) LOI, SiO_2 and CaO - (2 days)
 c) B_2O_3 (exceptionally) - (1 week)

3) Chemical Analyses of Semi-Products :
 a) LOI, SiO_2, Al_2O_3, Fe_2O_3, CaO and MgO - (2 days)
 b) LOI, SiO_2 and CaO - (2 days)
 c) B_2O_3(exceptionally) - (1 week)

4) Chemical Analyses of Chrome Ore :
 a) LOI, SiO_2, FeO, Al_2O_3, CaO, MgO and Cr_2O_3 - (1 week)

5) Chemical Analysis of Flaked Graphite :
 C %, Ash Content : (3 days)
 Grain Size

6) Grain Size Determinations :
 a) 3, 5, 10, 15 and 25 mm (3-25 mm Raw $MgCO_3$) - (1 day)
 b) 3,5,10,15,25,40 and 60 mm(3-60 raw $MgCO_3$) - (1 day)
 c) 25, 40 and 60 mm (25-60 mm raw $MgCO_3$) - (1 day)
 d) 1, 3, 5, 10, 15 and 25 mm (calcined MgO) - (1 day)
 e) 3, 5, 10, 15 mm (Semi-Products) "A" - (1 day)
 f) 1, 2, and 3 mm (Semi-Product) "B" - (1 day)
 g) 5, 10, 20, 50 and 100 mm (Lumpy Chrome ore)- (1 day)
 h) 0,1; 0,5; 1, 2, and 3 mm (D-20 chr.ore conc)-(1 day)
 i) 0,1; 0,5; 1, 2, and 3 mm (D-26 " " " - (1 day)
 j) 0,1; 0,2; 0,5; 0,75 and 1 mm (Flaked graph.)- (1 day)

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7. <u>Physical Properties Determinations</u> :

a) <u>Bulk Density</u> - (1 day)

- Raw Magnesite
- Chrome Ore and/or Concentrate

b) <u>Density</u> - (1 day)

- Raw Magnesite
- Chrome Ore and/or Concentrate

c) <u>Weight of 1 litre of Volume</u> - (1 day)

- Raw Magnesite
- Calcined MgO
- Semi-Products ("A" and "B")
- Crushed Chrome Ore and Concentrates
- Flaked Graphite

8. <u>DTA-Determinations</u> - - (1 day)

- Raw Magnesite (various grain sizes)
- Calcined MgO
- Semi-Products ("A" and "B")

9. <u>X-Ray-Patterns</u> - (1 day)

- Raw $MgCO_3$ (various grai sizes)
- Calcined MgO
- Semi-Products ("A" and "B")
- Chrome ore and Concentrates

10. <u>Electron-Micro-Probe</u> - (1 week)

- 3 -60 mm Raw Magnesite (various colours) Distributions of SiO_2, Cao, and MgO

11. Reactivity of Calcined MgO - (1 day)

Development of a suitable Testing Method and Determinations of :

- Various Samples from Trial Tests
- Various Samples from Main Test.

- . - . - . - . -

ANNEX No. 2.

CURRICULUM VITAE

NAME: JOSEPH MAPIRAVANA

SPECILISATION: CHEMISTRY & GEOLOGY

FELLOWSHIP AWARDED: AUS BURSARY

FIELD: BSc. 1983

PLACE: UNIVERSITY OF ZIMBABWE
HARARE

DURATION: 4 YEARS

WORK EXPERIENCE

A. University Vacations (1981 - 1983)

Employer: University of Zimbabwe
(a) Department of Chemistry
(b) Institute of Mining Research

Post(s) : Research Assistant

Duties : (i) Setting up experiments
(ii) Analytical chemistry
(iii) Compiling catalogues for XRF and XRD standards
(iv) Interpreting experimental results

B. Full-Time (1984 - 1987)

Employer: Department of Metallurgy, Ministry of Mines

Post(s) (1/4/1984 - 1/4/1986): Chemist and Acting Chief of the Ceramics Non-metallics section as from 1/9/1984

Duties: (i) Administering the ceramics section.
(ii) Testing, evaluating and upgrading non-metallic raw materials) or products.
(iii) Research and development of non-metallic minerals based products (including fine ceramics and refractories)

(iv) Understudying and assisting UNIDO experts on Projects on non-metallics in Zimbabwe.

Post(s) (1/4/1986 - present): Clay Specialist and Chief of the Ceramics Section.

Duties: As above

Specific UNIDO sponsored projects undertaken in this post include:-

(i) Testing, evaluating and processing of alumosilicate materials (clays kyanite etc) for the production of fine ceramics and refractories

(ii) Laboratory and semi-industrial beneficiation of Kadoma magnesite for the production of basic refractories

(iii) Testing and evaluating a whole spectrum of Zimbabwean non-metallic minerals for the compilation of a geological inventory on Zimbabwean non-metallic minerals

(iv) Technology of fine ceramics production viz: technical porcelain products sanitaryware production, manufacture of wall tiles and the development of fine ceramics glazes from mainly Zimbabwean raw materials.

(v) A preliminary market survey and a pre-feasibilty study on the production of Zimbabwe's non-metallic minerals and products supply and demand with a view to delineating the main lines for the development of the non-metallic minerals sector in Zimbabwe.

FURTHER PROFESSIONAL TRAINING

1. Attended the first world congress on non-metallic minerals held in Belgrade, Yugoslavia.

2. Attended a 2-week technical workshop on the complex utilisation of non-metallic minerals in developing

countries, held in Pilsen, Czechoslovakia.

3. Undertook UNIDC fellowship programmes in Hungarian and Polish factories and research institutes as follows:-

A. HUNGARY (2 MONTHS)

1. Programme:- (i) Technology of manufacture of sanitaryware.

Place

(ii) porcelain tableware production technology
(iii) floor and wall tile production technology
(iv) majolika production
(v) production of kiln furniture - cordierite and SiC
(vi) energy diagnostics
(vii) constructional and design aspects of a pilot plant rotary frit kiln

Place: Alföldi porcelaingyar in Hödmezövasarhely and Budapest Porcelangyar in Budapest

2. Programme: Organisation of research and problems associated with:-
- fine ceramics
- silicate chemistry
- glass technonogical measurements
- production of refractory cements
- some special ceramics

Place: Zolnay Porcelanyar in Pécs.

4. Programme:-

Technology of production of low and middle tension insulators and the production of other technical ceramics.

Place:- KÖRBANYAI PORCELANGYAR (KÖRPOC) IN BUDAPEST

5. Programme:-

Production technology for magnesite based refractories and consultations on the application of various basic refractories and on the design of laboratory furnaces.

B. POLAND (2 MONTHS)

Programme:-

a) Technology of manufacture and application of refractories: raw materials - their upgrading, testing and processing unit operations in the refractories technology: batch preparation; shapes forming (including pressing), drying and firing; interoperational controlling; plant equipment and the organisation of production; standard and unconventional methods of testing refractory materials and products. Technology of application of refractories in iron and steel works.

b) Technology of manufacture of special ceramics: crucibles, tubes, supports abrasion resistant elements, etc.

c) The problems of research in refratories and special ceramics.

d) Design of industrial furnaces.

Places:-

1. Biuro Projektwo Przemyslu materiatow ogniotrwalych "Bipromog" - Gliwice
2. The refractories institute - Gliwice
3. Magnesite refractories plant (Zaklady magnezytowe in Ropzyyxw)
4. Factory for the production of alumosilicate and high alumina refractories.

(Skawinske Zakladay Materialow Ogniotrwalych in Skawina)

5. Alumosilicate to high alumina factory (Zaklady Surowcow Ogniotrwalych "Gorka" in Trzebina).

6. Katowice Iron Works (Huta Katowice)

7. Kracow Iron Works (Huta im Lenina)

ANNEX No. 3 .

CURRICULUM VITAE

Name:	Luckstone MAREYA
Sex:	Male
Date of Birth:	25th May, 1961
Age:	26 years
Place of Birth:	Harare/ZIMBABWE
Marital Status:	Single
Nationality:	Zimbabwean
Citizenship:	Zimbabwean
Residential Address:	20, Marimba Park, Deka Road, Harare/ZIMBABWE
Postal Address:	P.O. Box ST 211, Southerton, Harare/ZIMBABWE
Business Address:	DEPARTMENT OF METALLURGY, P O Box 8340, Causeway, Harare/ZIMBABWE
Home Phone Number:	62821
Business Phone Number:	726629/0

EDUCATION

1967 - 1968	Yamurayi Government School	
1968 - 1971	Wadzanayi Government School	
1972 - 1973	Hartzell Primary School	
1974 - 1977	St George's College G.C.E 'O' Level with following results:	
	Chemistry	A
	Mathematics	B
	English Language	B
	English Literature	C
	Human Biology	B
	Geography	A
	Physics (1978)	B
	History	C
	Relig. Studies	C
	French	C
1978 - 1979	'M' Level:	
	Chemistry	3
	Pure & Applied Mathematics	6

1980 - 1981	Commercial Careers College: G.C.E. Advanced Level Chemistry Pure & Applied Mathematics	 B D
1982 - 1985	Tertiary Education: University of Zimbabwe BACHELOR OF SCIENCE GENERAL DEGREE	

Mathematics (1982)

(1) Pure Mathematics
(2) Analysis
(3) Linear Algebra
(4) Statistics

Geology (1982)

(1) Crystalography
(2) Mineralogy
(3) Pateotology
(4) Petrology
(5) Stratigraphy of Zimbabwe
(6) Mapping and Geomorphology

Biochemistry (1983 - 1985)

(1) Mathabolic Pathways and inborn errors in Metabolism
(2) Nutrition, Bioenergetics, and Enzymology
(3) Drug Metabolism
(4) Hormone Control at Molecular level
(5) Nucleic acids and Genetics
(6) Industrial Microbiology
(7) Immunochemistry
(8) Radiochemistry
(9) Spectroscopy as applied to Biochemistry
(10) Separation techniques
(11) Biochemistry of Biological Structures

Chemistry (1982 - 1985)

(1) Inorganic and analytical Chemistry:
(2) Systematic group Chemistry. Wet methods and instrumental methods of analyses. Organometallic and coordination Chemistry. Solvent extraction. Ion exchange, Spectrochemistry or complex ions. Chemistry of the Lanthanides. Extractive metallurgy.

(2) Physical Chemistry:
Quantum Mechanics. Statistical Thermodynamics. Ion equilibria. Electrochemistry. Thermochemistry. Colligative properties. Surface chemistry. Electric and magnetic properties of molecules. Thery of spectroscopy. Transport phenomena and Solution Kinetics. Phase Rule. Computer Science and its application to numerical approximations.

(3) Organic Chemistry:
Stereochemistry and Reactivity.

Spectroscopy and Structure. Organic syntheses, properties and uses of aliphatics and aromatics. Aromaticity. Advanced reaction Mechanics. Polynuclear aromatic Chemistry. Heteronuclear Chemistry. Biomolecules and carcinogens.

MAJOR SUBJECTS : Chemistry and Biochemistry

SUBSIDIARY SUBJECTS : Mathematics and Geology

FINAL YEAR RESULTS :	Chemistry	-	Grade III
	Biochemistry	-	Grade II
Overall Degree Classification		-	Grade III

EMPLOYMENT RECORD

July 1986 — Department of Metallurgy, Ministry of Mines, Sir James McDonald Avenue, Harare/ZIMBABWE

POST: Higher Technician

DUTIES :

July 1986 - Feb.87

i) Routine Mineral Processing of Ores

ii) Investigation into ores which do not respond to routine treatment.

iii) Investigation into applicability of recent advances in mineral extraction to our local needs.

March to present:

i) Routine analysis of non-metallic raw mat rials and quality control of ceramic products;

ii) Investigate the use of locally available non-metallic raw materials in the production of ceramic products.

HEALTH RECORD : No disability. No major illness

MISCELLANEOUS INFORMATION: Clean Class 4 Driver's Licence - 1980

FUTURE PLANS:

i) To study for a Post Graduate Course in Ceramic Technology

ii) To develop methods of upgrading local raw materials so they can be used in the production of those ceramic products which are at present being imported.

Harare, August, 1987

Annex No. 4 .

LIST OF EQUIPMENT TO BE PROVIDED FOR SEMI-INDUSTRIAL INVESTIGATIONS IN ZIMBABWE

1). Rubber Belt Conveyor that can also be mobile. Intended for feeding of semi-industrial rotary kiln with raw magnesite.

2). Semi-industrial Rotary Kiln for the planned semi-industrial investigations; the existing kiln in Eiffel Flats (under the roof could be used (10400 mm of length). The kiln has to be adopted and mechanically repaired, as well as lined with refractory bricks of adequate quality for the working temperature of 1200°C.

For this kiln an adequate burner is to be provided, to use light diesel oil or earth gas, enabling proper calcination of raw magnesite up to 1200°C, according to the kiln capacity.

Prior to the beginning of work, the kiln is to be mechanically tested in cold state.

3). Optical Temperature Measuring Instrument to control working temperature in the rotary kiln during calcining. Its measuring range should be approximately 700°-1300°C, with accuracy of ± 10°C. The instrument is to enable the whole quantity of raw magnesite to be as evenly calcined as possible, as well as to enable the temperature control at different levels.

4). Mixer for Wetting of Calcined Magnesite. For this process a mobile mixer could be used, like the one used for mixing of concrete in civil engineering. It should be about 100 litres of volume, or close to that, which can be obtained on the market - from regular serial production.

5) Containers made of zinc plated sheet, about 75 litres of volume (20 pieces). The containers are intended for taking over of calcined magnesite, after being wetted in concrete mixer. The 20 pcs are to ensure undisturbed work for 2 - 3 days.

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6). Vybrating screen, double-deck, with capacity of 200-250 kg/hour. As no special requests are made regarding construction of the screen itself (it is only desirable that it should be dedusted), an ordinary screen from regular production could be used, having about the required capacity, which can be found in Zimbabwe. Appertures of the screen sgould be as follows: a) the upper screen: 3 x 3 mm ; b) the lower screen: 1 x 1 mm. The screens used in civil engineering could be applied for this purpose.

7). Cold Crushing Tester with the Attachement for pressing of the specimens to be tested.

The tester is indispensable for development of new products in fine and coarse ceramics and construction materials. It would considerably facilitate the work and extend the activities of the Department of Metallurgy, Harare. An offer of the best known European producer was acquired (TONI-MEL Prüfsysteme, D-6707 Schifferstadt, No. 1982/85/G of 16th October 1985). A copy of this offer has been submitted to Zimbabwean partner.

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Annex No. 5 .

R E C O M M A N D A T I O N S

How to prepare the rotary kiln at Eiffel Flats for the calcining of magnesite

1). Please provide a bin and a (belt) conveyor, so that even feed of the kiln, and the measuring of the material (by wight or by volume) can be ensured.

2). Due to the relatively high working temperatures (up to 1200°C) it is advisable to reline (ca. 2.5 meter) the entrance of the kiln with the fire clay bricks, in order to avoid plastic deformation of the shell, as well as high abrasion of the same.

3). It would be very helpful to replace the existing thermometer by a thermocouple (up to 1400°C or higher), which should be built in in the same hole - for the control of the calcining process.

4). It would be, also, very helpful to ensure an optical pyrometer (up to 1400°C or higher), for taking the temperatures at various olaces in the kiln.

5). Continuous discharge of the kiln should be ensured in order to avoid contamination of calcined material, the weight of which should be possibly measured.

6). Fuel (diesel) oil pump and burner should ensure enough heat, for reaching working temperature of the kiln (1200°C) with the full capacity of feed.

7). All relevant data for the fuel oil (ash and sulphur content, calorific value, etc.) should be provided.

8). The kiln inside, as well as the platform around the kiln must be quite clean.

9). It is expected that the chemical laboratory at the site will supply necessary results for the raw magnesite and calcined material within one day.

Harare, Dec. 1986.

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ANNEX No. 6 .

COLLECTING OF REPRESENTATIVE SAMPLES
- RAW MAGNESITE -

Herewith we confirm to have taken from KADOMA MAGNESITE (PVT) LTD, Kadoma/ZIMBABWE, following representative samples :

1. <u>On Tuesday, 05. May 1987, and on Wednesday, 06. May 1987</u> :

About 40.o t of crushed and washed raw magnesite on 05. May, and about 20.o t on 06. May 1987, taken from the stock-pile at railway sites (weighing about 1,500 t according to the Mine evidence, and corresponding with the production of one month), containing particles from 3 - 25 mm, as prepared for delivery to South African consumers ;

<u>Procedure</u>:
From the mentioned stock-pile, having circumference of about 120 metres, and the height of about 1.6o metres , the samples weighing about 1 t of magnesite have been taken by front-end loader, as evenly spread as possible from the bottom up to the top, at the distances of about 2 metres apart. All sapmples taken have been unloaded in one self-unloading lorry. It was tried to reach some homogenization during unloading of front-end loader, by spraying the sample over the whole surface of lorry container.

Total weight of this sample has been determined by weighing out all three loads on the bridge scale in Kadoma.The whole quantity of this representative sample has been unloaded on a concrete surface close to the rotary kiln of "CTS"-plant of RIO TINTO, at Eiffel Flats, which has been later on used for the calcining test.

2. <u>On Friday, 08. May 1987</u> :

About 22.o t of crushed and washed raw magnesite taken from the vybrating screen (overflow) after primary crusher, containing particles from 25-60 mm.

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Procedure :

One showel (about 5 kg) has been taken every 5 minutes from the vybrating screen overflow and collected in the course of about eight working days. The collected quantity has been loaded by a front-end loader into one self-unloading lorry. Here, also, it was tried to reach some homogenization during unloading of the front-end loader, by dissipating the sample over the whole surface of lorry-container.
This representative sample has been also unloaded on a concrete platform close to the rotary kiln of "CTS"-plant of RIO TINTO, at Eiffel Flats, as mentioned above.

3. On Friday, 08. May 1987 :

About 12 t of the representative sample, containing the particles of 3-60 mm has been prepared in CTS-plant of RIO TINTO, at Eiffel Flats, in the following way :

- A quantity of 9.o t of the sample, mentioned under item 1. of this Annex, has been spread on the concrete platform close to the rotary kiln, and a quantity of 3.o t of the sample, mentioned under the item 2. of this Annex (i.e. 25-60 mm), has been dissipated over the firstly mentioned sample (3-25 mm). Thorough mixing of both samples has been repeated three times. The new sample consisted of 75 w. per cent of the particles 3-25 mm, and 25 w. per cent of the particles 25-60 mm. This proportion of both grain size classes has been found out from the mine management, as being typical for a very long period of time.

Provision has been made to avoid any contamination of the samples during the transportation, as well as during the time of keeping them stock-piled at the CTS-plant, at Eiffel Flats.

At Eiffel Flats, 08. May 1987.

UNIDO-Experts:

(Jovan Vlajcic) (Ivan Budimir)

For Dep.of Metallurgy:

(J.Mapiravana) (L.Mareya)

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ANNEX No. 7.

A PRACTICAL METHOD FOR LITRE-MASS DETERMINATIONS

Litre-Mass is the mass of one litre of a material, which is loosely filled in an appropriate measuring container. The litre-mass of the calcined magnesite represents one of its very important properties, showing the extent of its densification during the calcining process, and allowing a quick control of the same. This value is indispensable for the design of shutes, conveyors, silos, bunkers, etc.

Sampling: Depending on the nature of the material, and on the stability of the production process, sampling should be carried out every 1, 2, 4, or 8 hours, respectively. In the case of calcined magnesite, the sample taken from the rotary, or of shaft kiln should be about 100-120 kg, and let to cool down to 50°C. After thorough mixing, the representative sample should be taken by a sampler, or by spot-method. The sample, so prepared, should be used for the determination.

Container for this determination, preferably made of stainless steel, and having cylindrical form, with a volume of about 20 to 25 litres (D : H = 1.5- 2), which should be exactly predetermined by means of a water measuring jar. Appripriate dimensions of the container could be: D = 25 cm, and H = 40-50 cm.

Determination: The container should loosely be filled up with the material, so that a conical pile above the edges be formed. The excess of the material should be removed by a scrape, i.e with a hard object being pulled over the edges of container. During the filling up, and of scraping, container must not be shaken. After that, so filled container should be wighed out with an accuracy of ± 0.1 kg .

Calculation should be made by using following equation, i.e.:

$$\text{Litre-Mass} = \frac{G - G_1}{V} \quad \text{(kg/litre)}$$

where:

G = Weight of the full container, in kg,

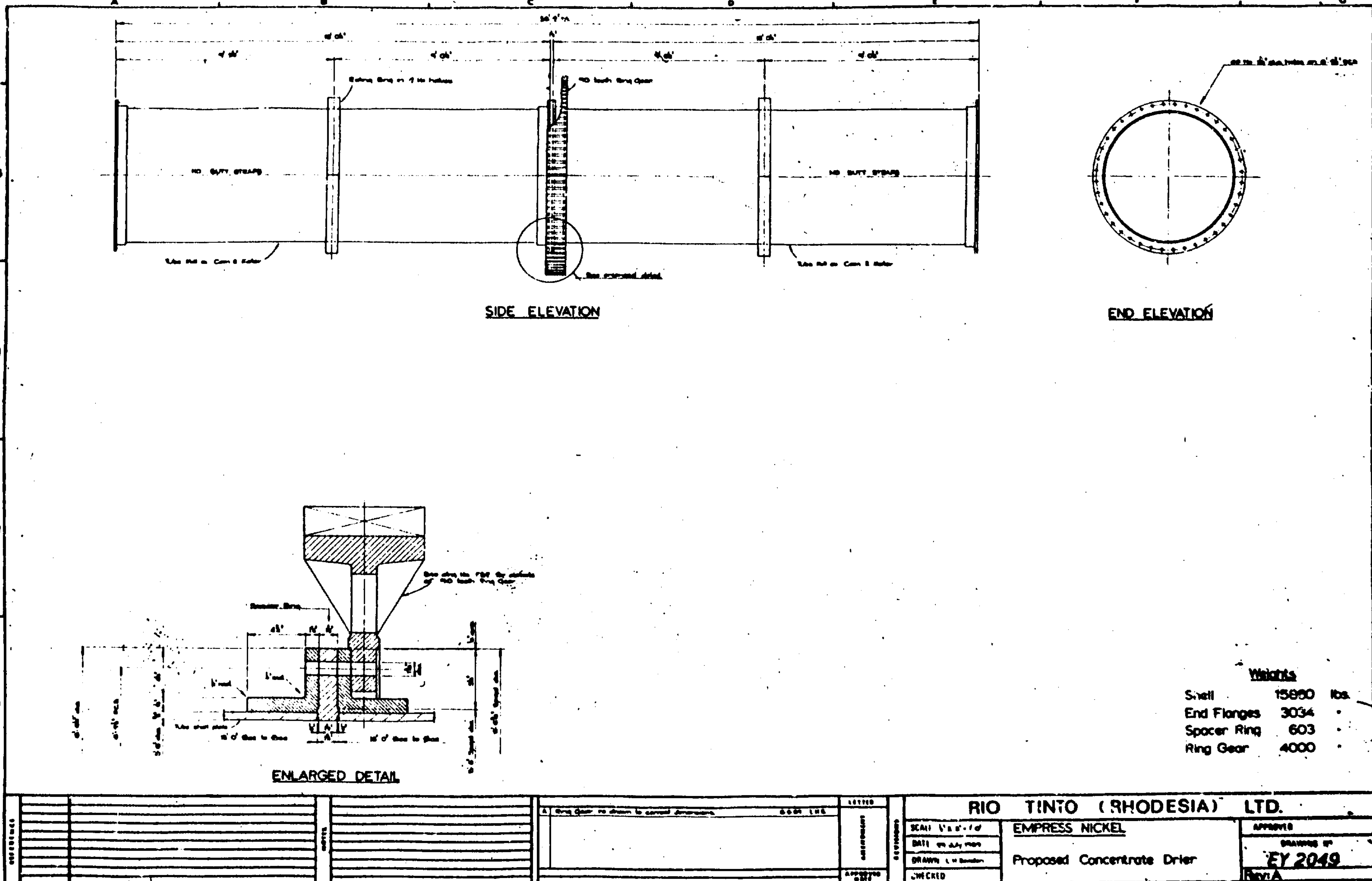
G_1 = Weight of the empty container, in kg,

V = Volume of the container, in litres.

During this investigations this method has proven to be very practical and relyable, ensuring reproducible results. But, for Litre-Mass-determinations every other standard method can be used. as well.

ANNEX No. 8 :

Sketch of the Rotary Kiln



ANNEX No. 9.

FUEL SPECIFICATION

Product: Automotive Gas Oil

Quality: Automotive Gas Oil (100 % Distillate meeting all Requirements of BS.2869:1970 Oil Fuels - Class A

	Typical Result	Specification Limits
Colour, ASTM		3,5 max.
Density, kg/litre @ 20°C	0,817-0,840	
Distillation:		
Recovery @ 350°C, % vol.		85 min.
Flash Point, PMCC, °C		66 min.
Viscosity, Kinematic at 37,8°C, cS		1,6-6,0
Redwood 1 @ 37,8°C, secs.		30-40
Cloud Point, max. °C		0
Ash, % wt.		0,01 max.
Sediment, % wt.		0,01 max.
Water Content, % vol.		0,05 max.
Carbon Residue, Ramsbottom, on 10% residue, % by mass		0,2 max.
Sulphur Content, % wt.		0,5 max.
Corrosive Sulphur, Cu-Strip		1B max.
Neutralisation Value:		
Strong Acid No., mg KOH/g		Nil
Total Acid No., mg KOH/g		0,50 max.
Diesel Index		58 min.
Calorific Value, Gross MJ/kg	45,7	45,1 min.
Calorific Value, Gross MJ/lit.	37,9	37,4

Remark: Data obtained from the Supplyer (SHELL)

ANNEX No. 10.

COLLECTION OF 205t REPRESENTATIVE SAMPLE (3 - 25mm)

Selective mining is undertaken at Kadoma magnesite mine. The grade of the ore extracted should always conform to the following chemical specifications:-

SiO_2	1.0%	(Max)
CaO	4.0%	(Max)

About 80t/day are now extracted from Monday to Friday inclusive. As this amount falls far short of the capacity of the existing crushing plant, the extracted ore is first stockpiled before crushing on alternate days of the working week.

The 205t of 3 - 25mm magnesite ore used in the project represent part of ore selectively extracted over 5 days of the regular production, from various points of the mine workings with a suitable grade and then crushed over 3 working days.

COUNTER-PART TEAM

DATE: 14/8/82 J. Mapiravana L. Mareya

ANNEX No. 11.

REPORT ON A VISIT TO THE KADOMA MAGNESITE MINE, KADOMA, GWERU MINING DISTRICT

Visited : 11.06.87

By : S. SIMANGO

INTRODUCTION

The mine was visited at the request of the Director for Metallurgy to review the situation at the mine re-ore reserves and development in anticipation of the proposed Magnesite-refractories plant. This was also a familiarisation tour for the writer, who is compiling a Magnesite Report for the Mineral Resources Series.

The writer was accompanied underground by the Shift Boss, Mr J. Hastings.

The majority shareholding in the Company, which is incorporated in Zimbabwe, is held by Vereeniging Refractories Ltd., of South Africa.

LOCATION AND ACCESS

The mine is located on Barton Farm approximately 12 km south east of Kadoma. Access from Kadoma is by tarmac road for about 9 km and then by gravel road due east for 3 km.

WORKINGS

Development has reached 6 level but no work is being carried out there. Most work is between 2 and 5 levels.
5 level east drive was developed in the period 1984-85 for talc but with no production. This venture reduced development for magnesite hence the current low ore reserves. Most of the development is now in the west drive of 5 level, with a small quantity of ore reserves in the south drive (no quantities given).

There is very little work being done on 4 level. Bigger scale operations are on east drive level 2. However mining on this level has been haphazard, this being prompted by the selective mining practised at the mine.

A new mine has been developed on the far east orebody where production is expected to begin from 6 level to 11 level.

ORE RESERVES

The anticipated demand for raw magnesite by the magnesite-refractories plant is put at 120 000 tonnes per year to produce about 50 000 of refractory products, for both domestic and export markets, particularly for PTA and SADCC countries. The South African market should also be reviewed in terms of continuing or discontinuing exports. If exports of raw magnesite are to be continued this will increase anticipated production to 144 000 tonnes per year. In view of this the delineation

of more/...

of more ore reserves will be of top priority. The currently quoted ore reserves are as follows:

Proved Reserves	74 000 t
Ore in sight	27 000 t
Indicated Reserves 5 and 6 levels	104 000 t
Sub-Total	205 000 t
Indicated reserves in far East Zone down to 11th level	346 000 t
Total Ore Reserves (all categories)	551 000 t

These ore reserves would give the mine a running life of less than 4 years from the present at the anticipated production requirements.

MINING METHODS EMPLOYED

Highly selective mining is practiced employing:

1. Underhand stoping into vertical ore raises. This method is used in all major stope.
2. Overhand Stoping. This is only used where the vertical extend of on-grade material is limited to approximately 5 metres.
   Stope sizes vary greatly from widths of 8,3 metres up to 15 metres. Stope sizes are determined by the grade of ore.

   The ground is easy to break for mining but very stable with no ground support required.

GRADE CONTROL

Extremely selective mining is practiced. Sludge samples are collected from 1 metre holes drilled at approximately 1,5 metre intervals, in all stope faces prior to drilling the face for blasting.
Samples are assayed on site with independent checks being done once a week on random samples. Checks are done by Rio Tinto Analytical Laboratories. Samples are analysed for loss of ignition, insolubles i.e. silica and lime.

MARKETS

Currently the mine exports an average 2 000 tonnes of raw magnesite to South African manufacturers of refractory bricks, with a small volume of less than 2 per cent of gem quality magnesite going to another South African buyer. The raw magnesite is sold in the form of crushed ore (+4 mm - 25 mm).
Local consumption is less than 3 000 tonnes a year. The consumers are G & W Industrial Minerals, 2 800 tonnes and W.S. Craster Ltd., 138 tonnes.

PROBLEMS/...

PROBLEMS FACING THE MINE

The most significant problems facing the mine are:

1. Erratic grades of the ore: Even with stream lined selective mining, this one factor will always have to be reckoned with.

   The erratic grades are complicated by fault tuffa referred to as "mud fissures" by the miners. Where these are thick they tend to dilute the ore. Overall fissures tend to thin-out with depth and their effect reduced.

ii. Water: The mine and the surrounding area is very dry. Several boreholes have been sunk by the mine in an effort to find water reserves but all were dry. Currently all water used by the mine is bought from Kadoma Municipality. There is a threat to this supply if a new water works is commissioned which will use a different pipe line. This issue should be raised with the appropiate authorities.

iii. Geology: There is no geological input during development work. The company geologist, who is resident in South Africa, only visits the mine for a few days in a year and his last visit was a year ago at the time of reporting. It should be appreciated that with this type of deposit a lot of geological input is required and more so with the anticipated increase in production targets.

Others

i. Lack of feed back from customers.

ii. Lack of communication with senior management. It appears the mine is considered only as a supplier with no interest shown in its day to day running etc.

iii. Shortage of spares. This is a problem common to the mining industry in Zimbabwe which requires an indepth review.

CONCLUSIONS AND RECOMMENDATIONS

Although the mine is currently meeting its market requirements, in view of the anticipated increase in production to meet demand from the magnesite refractories plant the following recommendations are made.

i. There has to be a concerted development effort to delineate more ore reserves. This can only be accomplished satisfactorily if all levels of the mine have been completely mapped and sampled. For this a comprehensive geological input is required, both underground and on surface.

ii. The present haulage system needs extensive renovation. Even with the current small production of 2 000 t/month, the system is still very labour intensive and inefficient. A mining engineering report on this is imperative.

iii. The/...

iii. The selective mining currently practiced should be streamlined to accommodate slightly lower grade ore. This will greatly increase ore reserves. However, this can only be achieved by upgrading the lower grade ore using a very efficient beneficiation plant. This will entail more sophisticated ore handling facilities (see above). The Pande Mine is referred to on this.

It is worth noting here that while the mine sells its raw product at about Z$28 per tonne, G & W beneficiates and resells at Z$328 per tonne.

iv. An appraisal of the ground conditions is required particularly from 2 level upwards.

v. Analytical techniques currently used in grade control procedures need a thorough review.

COMMENTS

The magnesite body is estimated to be 2 km long by 100-200 metres wide. The current mine has been developed over only 375 metres strike to 6 level. Even with high grade ore comprising less than 20 per cent by volume of the total magnesite body, the deposit is of a very high potential and should be fully developed to allow maximum recovery of the magnesite.

Mr Odendaal, the Manager is thanked for releasing confidential reports for the writer's reference.

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ECONOMIC GEOLOGIST

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SS/GM

ANNEX No. 12 .

PROPOSED PROGRAMME OF WORK

II. Phase of semi-industrial investigations to be carried out in Yugoslavia/Europe

1. Necessary Raw Materials:

1.1 Semi-products: SP - A , and SP - B

Designation	Quantity
SP-21/3	1,300 kg
SP-24/3	1,000 "
SP-25/3	2,100 "
SP-26/3	1,300 "
SP-27/3	1,250 "
SP-28/3	1,300 "
SP-29/3	1,850 "
SP-30/3	2,550 "
SP-1/3	1,950 "
SP-2/3	2,050 "
SP-3/3	2,000 "
SP-4/3	1,800 "
Total	20,450 kg

Designation	Quantity
SP-24/16	950 kg
SP-25/16	1,750 kg
SP-27/16	1,150 "
SP-2/16	1,150 "
SP-3/16	1,250 "
Total	6,250 kg

1.2 Chrome ore Concentrates: (Mtoroshanga mine):

D-20 2,000 kg

D-26 2,000 kg

1.3 Flake Graphite (LYNX-Mine):

A-15 1,000 kg

1.4 Determination of the Properties of all Raw Materials:

- Chemical Composition,
- Mineralogical Composition,
- Microstructure,

Physical Properties:

- Density,
- Bulk Density
- Litre-Mass

1.5 Evaluation of the Results

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2. Preparation of Semi-products: SP-A and SP-B for Briquetting

2.1 Fine milling of about 20 t of SP-A, and about 6 t of SP-B

2.2 Determination of Properties of finely milled SP-A and SP-B
- Grain Size Distribution
- Litre-Mass

2.3 Evaluation of the Results

3. Production of Dense Briquettes, about 14 t of SP-A, and about 4 t SP-B

3.1 Choice of the operational conditions for briquetting process

3.2 Determination of the green briquettes properties:
- Bulk Density,
- Litre-Mass

3.3 Determination of specific consumption figures:
- for finely milled SP-A
- for finely milled SP-B
- electric energy, etc.

3.4 Evaluation of the Results

4. Dead-burning of the briquettes in semi-industrial kiln

4.1 Choice of the operational conditions for dead-burning process

4.2 Regular Control of dead-burning process:
- Chemical Composition,
- Bulk Density

4.3 Production of 10-12 t of dead-burned magnesite DBM-A, and o 4 t of dead-burned magnesite DBM-B

4.4 Determination of properties of DBM-A and DBM-B:
- Chemical Composition
- Mineralogical Composition
- Microstructure
- Size of periclase crystalls
- Physical properties:
  - Density
  - Bulk Density
  - Porosity
  - Grain Bulk Density
  - Hydration Resistance

./.

4.5 Determination of Specific consumption figures:

- for briquettes
- for fuel
- for electric energy

4.6 Evaluation of all results

5. Production of about 10-12 t of test bricks (magnesite-, magnesite-chrome-, and magnesia-carbon-bricks) out of DBM-A

5.1 Preparation of components and batch mixing

5.2 Pressing of test bricks

5.3 Drying and/or tempering of test bricks

5.4 Firing of test bricks

5.5 Determination of properties of all three types of test bricks:

- Macroscopic Appearance
- Chemical Composition
- Mineralogical Composition
- Cold-crushing Strength
- Apparent Porosity
- Refractoriness-under-Load
- Thermal Shock Resistance
- Linear Expansion Coefficient

5.6 Determination of Specific consumption figures for:

- Raw Materials
- Fuel
- Electric Energy

5.7 Evaluation of all results

6. Findings and Recommandations

7. Preparation of Final Report (10 copies + Master Pages).

- . - . - . - . -

Remark: The extension of the Programme of Work, by including 6 t of semi-product "B" (SP-B), has been recommanded in order to enable the determination of optimal operational conditions for:

a) dead-burning process for DBM-B, and
b) stabilizing process for DBM-BS.

ANNEX No.

ZIMBABWE GERMAN GRAPHITE MINES (PRIVATE) LIMITED

P O BOX 200, KAROI

LABORATORY ASSAY OF SAMPLE

DATE 26.5.87

SAMPLE NO. 6

CONSIGNEE: Department of Metallurgy
Workington
Harare

GRAPHITE SAMPLE: : Flake A 15

CARBON CONTENT: : 90/92%C

APP. DENSITY: : 580 gr/ltr.

SIFTING ANALYSIS: :

5th Bags	15th Bag
+ 315 = 30.0	+ 315 = 30.2
+ 200 = 44.8	+ 200 = 43.4
+ 160 = 14.4	+ 160 = 15.0
+ 100 = 10.4	+ 100 = 11.0
- 100 = 0.4	- 100 = 0.4

QUANTITY APPR. : 20 Bags

MARKING: : Yellow Paint

DESPTACHED ON: :

PER : :

ATTENTION OF: : Mr J.J.Bungu

TO: LYNX
IDC
GK
MMCZ
CONSIGNEE

REMARKS: 1-This 1 tonne is representative for April and May 1987 production

2-The sample is taken from the 5th and 15th bags

SIGNATURE: Michael Dana

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