

# Magnesium – How China Beat Rest Of The World

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## Introduction

China has become the largest producers of Magnesium metal in the world, supplying about 75% of the world's magnesium. The growth of Magnesium industry in China is a fascinating story. The price of magnesium before entry of China was approx. \$ 2500 to \$ 2700 approximately 1.7 times then prices of Aluminium.

The production capacity of Chinese magnesium industry from being negligible in 1993 is now estimated at 600,000 tons. The price of magnesium ingot fell from \$2500-2700 to about \$ 1350. They rose later on to about \$1650- 2100 FOB China and have been hovering about this price band with one or two spikes or depressions for brief periods. The result has been world wide turmoil in the magnesium industry resulting in large scale closures in USA, Europe, and abandoning of almost all on going projects with horrendous losses.

Is it by mere luck or deliberate design? Is it a triumph of strategic planning based and swot analysis? Let us look at all facets of Magnesium,

## Magnesium properties

Magnesium metal is lightweight silver coloured metal having the following properties

|                        |                         |
|------------------------|-------------------------|
| Symbol                 | Mg                      |
| Atomic weight          | 24.312                  |
| Density                | 1.74 gms/cc             |
| Melting point          | 650 C                   |
| Latent heat of fusion  | 88 Kcal/kg              |
| Sp. heat               | 0.245                   |
| Electrical resistivity | 4.46 microohms-cm       |
| Thermal conductivity   | 0.37 cal/cm/sq.cm/sec/C |

It is the lightest of metal that can be used for structural work. It is 35% lighter than aluminium, its thermal and electrical conductivity are close to that of Aluminium. It is abundantly available in nature being approx 2.6 % of the earths crust.

## Production Of Magnesium

Magnesium can be produced either from a pyrometallurgical process (thermal magnesium oxide reduction) or by electrolysis from magnesium chloride containing molten salt. The latter is the dominant process with about 75% of the total production. There are five thermal reduction processes and eight electrolytic process that have been used in the past or being used at present. Different variations of both processes exist and will be described.

It should be noted that several technical challenges are faced with magnesium production that are usually not present with the production of other non-ferrous metals as clearly highlighted,

« First, magnesium is lighter than the cell baths (density of molten magnesium is about 1.58gms/cc at 700°C) used for electrolysis. This means that the magnesium will float on the surface of the cell and so some means must be devised to collect the magnesium into a compartment where a chlorine atmosphere is not present.

Next, the magnesium will react readily with O<sub>2</sub>, and burn at its melting temperature and above. Care must, therefore, be taken with the collection and casting of the metal so as to prevent metal loss and contamination of the finished product.

Finally magnesium must be handled at temperatures very close to its freezing point (generally at temperatures below 700°C) because of its tendency to burn. Although its heat capacity and heat of fusion are close to that of aluminum, magnesium tends to form a spongy material when it is exposed to the air and starts to cool. This causes some further difficulty in handling the metal, particularly when the final ingot shapes must be formed. »

## Thermal Reduction Processes

Nearly 75% of the world magnesium is produced via pyrometallurgical technologies. Many thermal reduction processes exist. Industrial applications show that the raw material is usually magnesium oxide. If a carbonate source is to be used, it usually requires turning the feed to an oxide form in a feed pre-treatment (calcination). The main difference between the two processes to be described is that the slag produced in the Pidgeon process is solid while it is liquid in the Magnetherm process.

### **Pidgeon Process**

During the period of high demand created by World War I, a Canadian researcher, Dr. L.M. Pidgeon, first proposed the chemistry underlying this process. Timminco Ltd. in Canada and extensively in plants in China currently uses this pyrometallurgical reduction. The process uses an externally heated retort (T~1,200°C) under vacuum (0.025 mm Hg). Figure 1 gives a representation of a Pidgeon's process retort

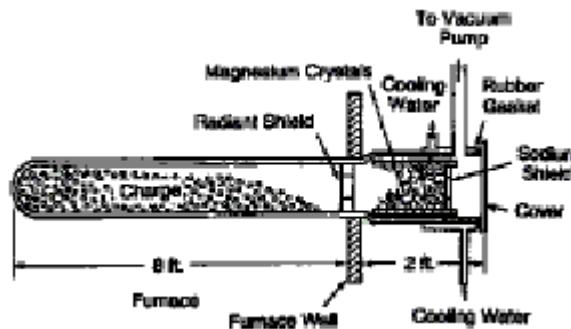
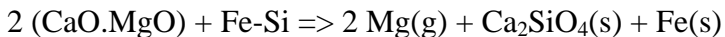


Figure 1 Schematic of the Pidgeon's process retort

Most of the industrial applications of the Pidgeon process use calcined dolomite (CaO.MgO) as a feed, which is reduced with ferro-silicon as follow:



At the operating temperature the magnesium forms a vapor and it is condensed in a crystalline form known as 'Magnesium crown' of the highest purity in the industry (>99.95 % Mg). The solid slag, which consists of Ca<sub>2</sub>SiO<sub>4</sub>, iron and unreacted charge, is removed batch wise from the horizontal retort. Limitations of this process are the size of the retort to create the given temperature and vacuum as well as the high amount of labor required. This process was initially operated by Timminco Ltd, Canada and then abandoned.

A process used by Rima Industrial S/A in Brazil is very similar to the Pidgeon process with the difference that the reactor is heated internally allowing the operation at slightly higher operating temperatures. However, the rest of the operation is very similar the Pidgeon process.

This is the process that has been adopted in China because of the vast developments in ferrosilicon production. The Chinese saw an opportunity based on their current strength in another field namely Ferro alloys. The Chinese were a worried lot in the middle of 90's because they had build up large capacities in Ferro silicon, a product used in manufacture of steel, the price was ranging from \$127 to \$ 92 per ton between 1995 and 1999. They were looking out for uses for ferro silicon.

The Chinese have made the very limitations of the process into virtues. They are low capital cost, availability of cheap and productive labour, easy shut down and start up thus giving flexibility in production, no large infrastructure demands, etc,

### **Magnetherm™ process**

The Magnetherm process can be considered as an evolution of the Pidgeon process. The major difference is that electric resistance created inside the molten slag internally heats

the reactor. The chemistry behind this process is similar but the main differences are that weaker vacuum can be used because of higher operating temperatures and that the operation is semi-continuous. Moreover, the reactors are usually larger because the internal heating removes the size limitation to maintain high temperatures. Typical operating conditions for the Magnetherm process are a temperature around 1500°C and a pressure around 10 kPa. Figure 2 Illustrates the general layout of the equipment used in this process.

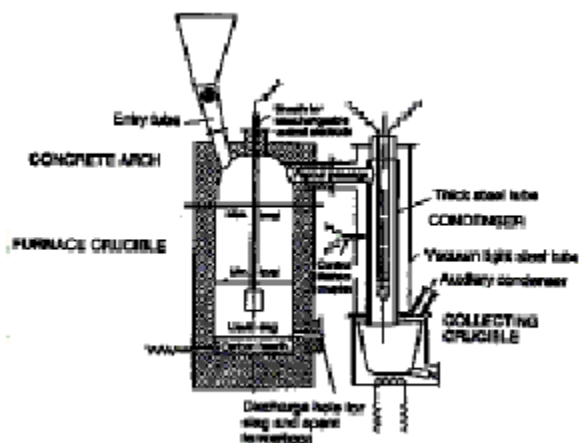
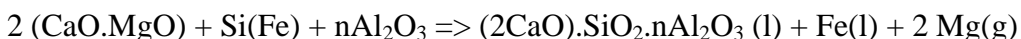


Figure 2 Schematic of the Magnetherm process equipment

In typical industrial operations, alumina ( $\text{Al}_2\text{O}_3$ ) is charged with calcined dolomite ( $\text{CaO.MgO}$ ) and ferrosilicon to produce a molten slag.



The reaction is favored by the lower silica activity in an aluminosilicate slag. The heat required is provided from the internal resistance of the molten slag using electrodes. Because of the addition of alumina, the slag is fluid allowing the slag layer to be tapped off of the reactor as a liquid and also making the resistance heating system possible. The magnesium vapor is condensed in the liquid state in a condenser. Limitations of this process are principally the extended downtimes resulting from vacuum operations and high product lost in the vacuum condenser due to ingress of air.

A process in South Africa “ Mintek process” is under development that operates at atmospheric pressure

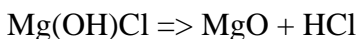
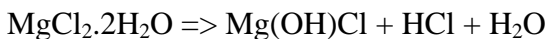
### Electrolytic Processes

Approx. 25% is produced using an electrolysis process. This method is based on the recovery of the magnesium contained in the raw materials as magnesium chloride, which is decomposed to produce molten magnesium metal and chlorine gas in an electrolytic cell. Modern electrolytic processes are fundamentally similar and can be divided in the following way:

- 1 - Feed Preparation (including drying)
- 2 - Electrolysis
- 3 - Casting

1- Feed Preparation: Feed preparation is a critical stage since it consumes about fifty percent of production cost and energy consumption. It essentially consists of the preparation of magnesium chloride stream from a magnesium bearing feed. Sometimes the feed is simply a magnesium oxide ore. In other circumstances, leaching has to be performed with HCl to extract magnesium from the raw material. Leaching kinetics and thermodynamics are generally favorable. Moreover, many different purification methods exist to remove deleterious impurities from the pregnant solution from selective precipitation to ion exchange.

The main difficulty in feed preparation is the production of anhydrous  $MgCl_2$  feed for the electrolysis cell. Anhydrous  $MgCl_2$  is needed in the electrolysis cell to decrease energy consumption. However, it is unlikely to be produced by common drying techniques under atmospheric conditions. As soon as the two water crystalline state of magnesium chloride is reached, significant hydrolysis occurs. The result would be the production of magnesium oxide instead of magnesium chloride from the following reactions:



The presence of undissolved magnesium oxide in the electrolyte leads to the formation of magnesium-containing sludge resulting in magnesium losses and severe process inefficiency. As it can be seen by the above reactions, a solution is to perform drying under a strong HCl atmosphere in order to stop hydrolysis reactions. The option used to dry magnesium chloride to anhydrous is mostly responsible for the difference between the different processes existing in the industry.

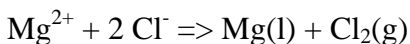
In 2000, all producers using the electrolytic process are using dehydrated magnesium chloride as a feed for the electrolytic cells. This can be referred as I.G. Farben process. Variations of this process exist from the type of feed, reagent availability, cost of energy, environmental regulations, and company know-how. Important features of the major alternatives are described later in this next section.

Until 1999 when it was discontinued, another alternative existed. It was to feed to the electrolysis cell partially dehydrated magnesium chloride ( $MgCl_2 \cdot 1.5H_2O$ ). This method was practiced by the Dow Chemical Company in Freeport, Texas and is known as the Dow Process. This plant used to be the largest in the world till its closure in 1999 for economical reasons. The main disadvantage of this technology was that it used the electrolytic cell itself as a final chlorinator and dryer for the feed. This was deteriorating

the current efficiency of the cell and imposed higher graphite consumption on the system. Moreover, higher amount of oxide sludges was formed increasing the metal losses in the cell.

## **2- Electrolysis:**

The production of magnesium from the magnesium chloride produced in the feed preparation is realized by standard electrolysis methods. The cell reaction is fairly simple:



The type of electrolytic cell varies from producer to producer. Often, the selection and design of the electrolytic cell are a result of the method selected to dry MgCl<sub>2</sub> and not the opposite.

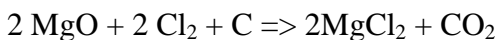
## **3- Casting:**

Casting is the last step of the production process. It involves the collection and casting of the magnesium produced in the electrolytic cell. As discussed earlier, magnesium is a highly reactive metal at moderate temperature and care must be taken during casting operations. Often, inert gas atmospheres (SF<sub>6</sub> and SO<sub>2</sub>) have to be used.

The use of SF<sub>6</sub> is becoming a problem, as its green house affect is some 28,000 times of carbon dioxide. The standards of emission currently are 0.5 kg/ton of Mg this likely to be revised to 0.06 kg/ton of Mg. Another possible candidate is refrigerant 134A.

## **I.G. Farben Process**

Pre World War II the technology used magnesium oxide as a starting material. However, this process can be used with magnesium carbonates or hydroxides with a feed pre-treatment (calcination). Molten anhydrous magnesium chloride is produced in a chlorinating furnace according to the following reaction at about 800°C:



Chlorine enters at the bottom of the furnace and molten magnesium chloride flows to the base where it can be tapped into crucibles for transfer to the electrolysis cells. Even if this reaction is exothermic, the temperature in the reactor has to be controlled with electrodes for better process performance. Norsk Hydro in Norway later practiced this technology. This process has environmental limitations because of the generation of unwanted chlorinated compounds due to the reaction of C and Cl<sub>2</sub> at the temperature of operation. Another drawback in using this technology is the batch operation of the reactor, which limits the productivity and creates problems for the automation of electrolytic cells.

## **Magcorp Process**

This process used in Utah (USA) can be considered as a modification of the I.G. Farben original process. The feed is a brine from the Great Salt Lake (~0.4 %  $\text{MgCl}_2$  which is four time more concentrated than the ocean). It is first dried in solar evaporation ponds to reach about 7.5-8.0 %  $\text{MgCl}_2$ . It is then treated with  $\text{CaCl}_2$  to remove sulfate by precipitation and passes to solvent extraction (kerosene) for boron removal. It is dried into a powder that has high levels of  $\text{MgO}$  and impurities. As discussed earlier, this feed is not adequate for electrolysis cells. Therefore, this powder is melted and chlorinated with  $\text{Cl}_2$  in a chlorinating furnace accordingly to the same reaction as the I.G. Farben process in presence of coke to achieve anhydrous magnesium chloride. The plant was very inefficient because of residual  $\text{MgO}$  after the chlorinator, the complex flow sheet, and the batch-wise metal transfers. It also had serious pollution problems similar to the original I.G. Farben process. These have been over come recently and the company is back from Chapter 11 and multimillion dollar lawsuits. The basic flow diagram indicates the process.

High levels of impurities in the  $\text{MgCl}_2$  have been shown to have an adverse effect on the efficiency of the electrolysis process. Modifications to the  $\text{MgCl}_2$  feed preparation process resulted in significant improvement in product purity. This was accomplished with the added benefit of an overall decrease in area operating costs of 10 percent.

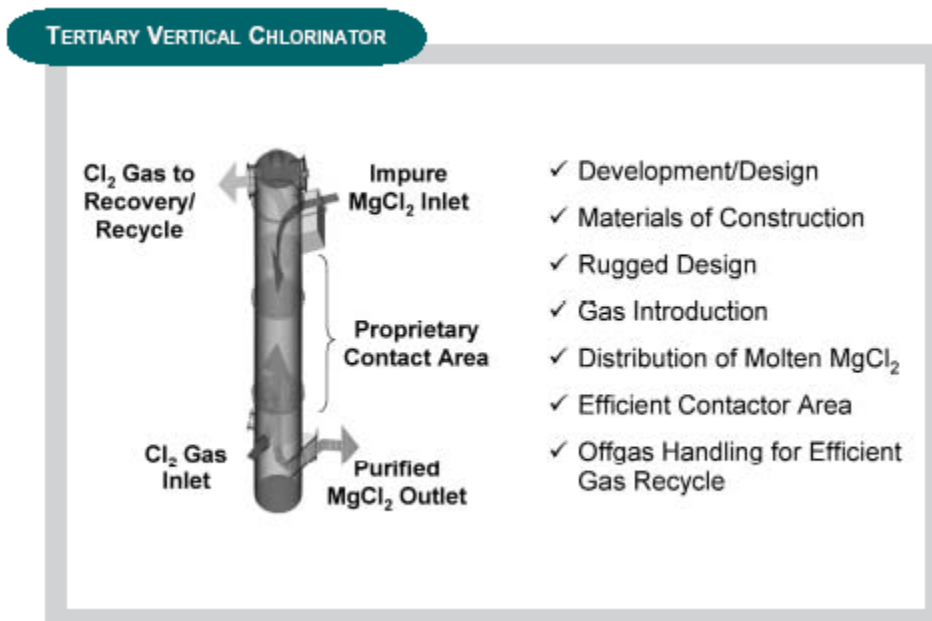


Figure 3 MgO Chlorinator

The success of this project enabled the design a high-efficiency electrolyzer for the magnesium cell rooms. The new cell design has improved and had significant impact on the MagCorp electrolysis system.

Replacing the existing electrolyzer direct-current (dc) power system with new rectifier and bus bar capacity, coupled with the new electrolyzer design, has resulted in improved efficiency. Actual performance levels of 13.27Kwh/kg magnesium (including all bus bars) have been demonstrated. In-cell power consumption has also decreased.

The increased scale of the new electrolyzers has provided a framework for reduced operating labor. Historically, MagCorp electrolyzers averaged 1.0 to 1.5 tons/day of magnesium, whereas the new cell design produces up to 3.1 tons/day of magnesium. This change, combined with the improved feed delivery system, has reduced area labor requirements by 83 percent.

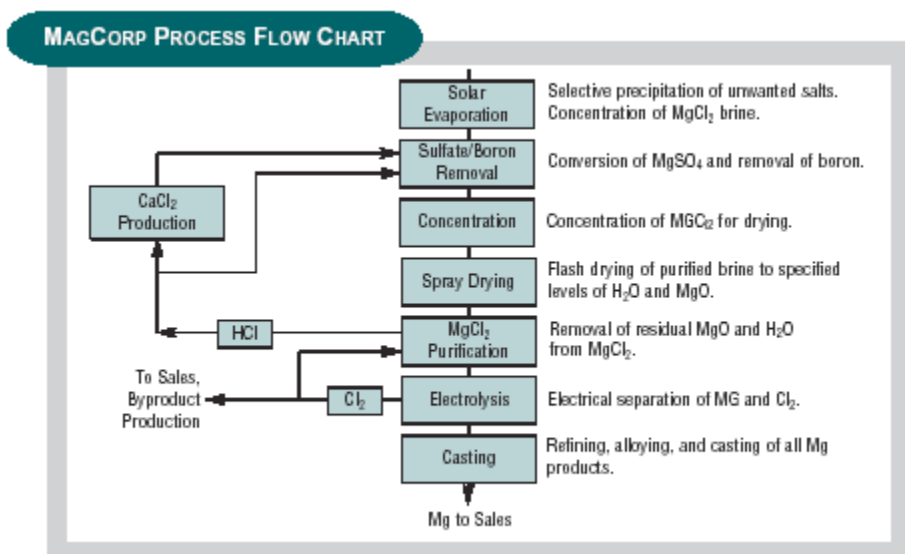


Figure 4, Magcorp process flow sheet

A few Indians have played a crucial role in the above developments

### Carnallite Process

In Ukraine a variation of I.G. Farben process is used. Dead Sea Works, in Israel, use this process. The dead sea works process was developed with the help of Russia. The property that carnallite (MgCl<sub>2</sub>.KCl) has to be somewhat easier to dry than magnesium chloride is exploited. Even if hydrolysis is reduced in comparison with pure MgCl<sub>2</sub>, a chlorinating furnace is still necessary to ensure low MgO content in MgCl<sub>2</sub> and insure high current efficiency in the electrolysis cells. The depleted electrolyte is recycled back to fluidized bed furnace. Flow lines for the feed and purge streams are integrated to the cell design. Moreover, pollution problems are reduced to a certain extent.

It also possible to operate the electrolyzers on batch basis, however, the electrical consumption is higher than for continuous process. The process allows producing magnesium from chloride raw materials: carnallite, bischofite, and aqueous solutions, containing magnesium chloride.



The process consists of the following stages (see flow sheet):

1. Synthetic carnallite production from aqueous solution of magnesium, potassium and sodium chlorides or by recrystallization of natural carnallite,
2. Dehydration of synthetic carnallite,
3. Electrolysis of dehydrated product with production of magnesium and chlorine.

To produce synthetic carnallite raw materials are fed into the process in proportions, which ensure product composition (wt.%) as follows:

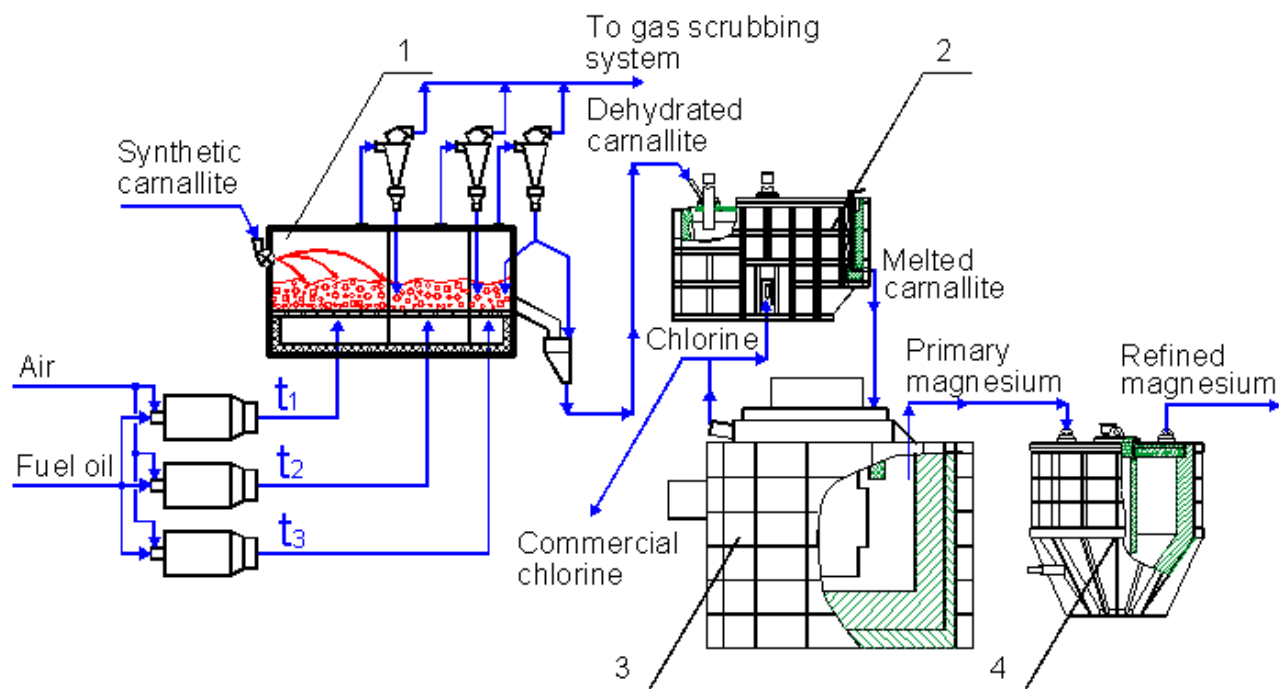
|  |             |
|--|-------------|
| Magnesium chloride ( $\text{MgCl}_2$ ) | 30-34       |
| Potassium chloride (KCl)               | 21-25       |
| Sodium chloride (NaCl)                 | 3.5-9       |
| Calcium chloride ( $\text{CaCl}_2$ )   | up to 2     |
| Moisture ( $\text{H}_2\text{O}$ )      | the balance |

Traditionally the dehydration of synthetic carnallite is carried out in fluidized bed furnaces with the use of hot gases produced by fuel combustion. Heat for dehydration may be partly supplied by contact with the heaters arranged in fluidized layer.

Solid dehydrated carnallite is melted and treated in chlorinators at 800°C in the stream of chlorine-containing gases.

Melted anhydrous carnallite is fed into electrolyzers for magnesium production, which may be connected into flow line. Crude magnesium after electrolysis is treated in furnaces for continuous refining. Part of chlorine produced by electrolysis is fed into chlorinators; the rest of chlorine is processed into commercial product. Spent electrolyte after granulation from the melt may be directly used as a potassium fertilizer, or treated additionally.

New technology of synthetic carnallite dehydration in fluidized bed furnaces within single stage with the production of solid high-dehydrated product suitable as the feeding of electrolyzers makes it possible to avoid melting and treatment in chlorinators. The off gases from fluid bed furnace are scrubbed with milk of lime and converted to granular calcium chloride. The off gases can be first scrubbed with water to produce some hydrochloric acid and then these gases are scrubbed with milk of lime to produce calcium chloride solution.



1. Fluidized bed furnaces
2. Chlorinator
3. Electrolytic cell
4. Refining furnace

Figure 5, Flow sheet carnallite process

Daily capacity per cell for batch process is 2000 kg, electrical consumption 13.7-15 kwh/kg mg

Daily capacity per cell for continuous process is 2500 kg, electrical consumption 12.7 to 14.5 kwh/kgmg The refining of magnesium would require another 0.5 kwh/kg of power. If granular magnesium is desired a further consumption of 0.2kwh/kg is needed.

### VAMI process

This is another variation in the carnallite process proposed in the CIS. This uses a double salt of with ammonium chloride, called ammonia carnallite.

The process allows producing magnesium from aqueous solutions, containing magnesium chloride, and oxide raw materials. In the first case chlorine produced by electrolysis is commercial product, in the second case it is recycle. The process consists of the following stages:

1. Saturation of purified magnesium chloride solution, including solution produced by leaching of oxide raw material by hydrochloric acid, with ammonium chloride to produce  $MgCl_2 \cdot NH_4Cl \cdot 6H_2O$ ,

2. Dehydration of produced hexahydrate in fluidized bed furnaces and its decomposition either in FB furnaces or in the smelters,
3. electrolysis of anhydrous magnesium chloride with production of magnesium and chlorine.

Saturated solution of magnesium and ammonium chlorides hexahydrate may be fed into FB furnaces without previous crystallization. Hydrolysis in the course of  $\text{MgCl}_2 \cdot \text{NH}_4\text{Cl} \cdot 6\text{H}_2\text{O}$  dehydration is less than in the course of carnallite dehydration. It allows producing anhydrous magnesium chloride, containing less than 0,3% of magnesium oxide, after decomposition in FB furnaces or to produce magnesium chloride melt, which is suitable to be used for feeding of multipolar electrolyzers.

Electrolyzers may be connected into continuous electrolyzers. In that case the dehydrated product ( $\text{MgCl}_2 \cdot \text{NH}_4\text{Cl}$ ) is decomposed in its head unit. The ammonium chloride is recycled back as seen in the flow sheet.

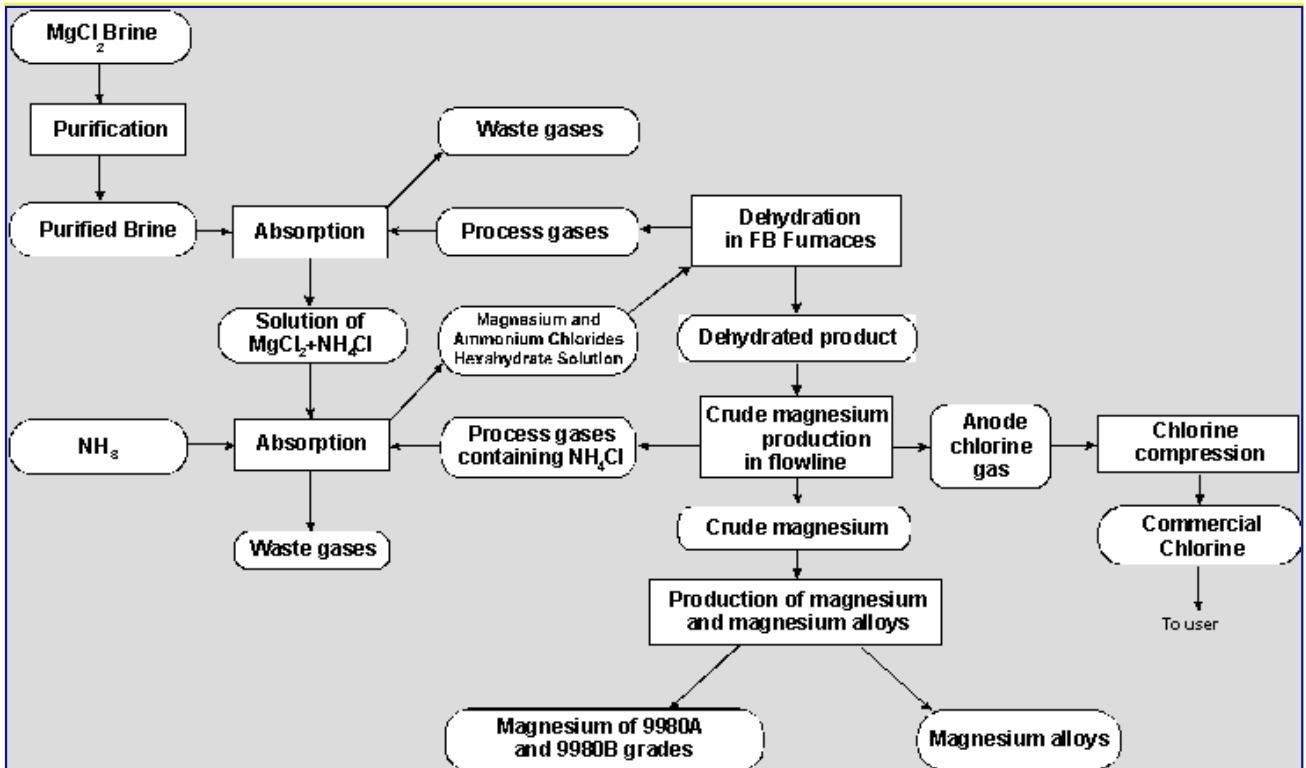


Figure 6 Flow sheet Vami process

### Norsk Hydro Process

At the moment, Norsk Hydro patented technology is the only one that dries to anhydrous  $\text{MgCl}_2$  without the use of a chlorinator. This technology is used in two Norsk Hydro plants, at Porsgrunn (Norway), now closed, and in Bécancour (Québec). The raw material, magnesite, is first leach with hot hydrochloric acid to produce a  $\text{MgCl}_2$  solution.

After filtration and ion exchange, this solution is dried to 50-55 %  $\text{MgCl}_2$  to produce prills. The key point of the process is the transformation of these prills to anhydrous  $\text{MgCl}_2$  in a series of fluid bed reactors. This patented technology uses strong HCl drying atmosphere to prevent hydrolysis reactions to occur. The resulting solid granular material can be conveyed to the electrolysis cell. Good sealing must be maintained to avoid contact with moisture since anhydrous  $\text{MgCl}_2$  is hygroscopic. However, when properly controlled, this system allows considerable more automation of the cells, better control of cell chemistry bath and lower operating cost over the previous technology. In addition, the absence of a chlorinator reduces considerably the level of pollution.

## India

CECRI had developed a multipolar cell for magnesium and a pilot project was put up in Tamilnadu. It was not a success for some reason and any way given the current cost of power the project would be unviable even if technically feasible.

## Uses

It has large number of uses such as

### 1. Magnesium alloys 90% magnesium content

#### 2. Chemical

Purification of gases

Organic synthesis

Grignard reagent

Organo metallic compounds

Explosives

2.31 Incendiary devices, signal flares, sensitizer, blasting, napalm, etc.

2.32 Pyrotechnics – fireworks etc.

#### 3. Electrochemical

3.1 Batteries

3.2 Cathodic protection electrodes

#### 4.0 Metallurgical

4.1 Alloying with aluminium, lead, nickel and zinc

4.2 Desulfurizing of iron

4.3 Scavenger- deoxidizing of copper and brass, debismathizing of lead, etc.

4.4 Thermal reduction

4.4.1. Reducing agent for production of beryllium, hafnium, titanium, zirconium, etc.

## Market

Magnesium is generally sold in form of 8 kg and 23 kg ingots. It is also sold in certain shapes for specific end uses.

The current segmentation appears to be

|                        |     |
|------------------------|-----|
| Magnesium alloys       | 40% |
| Diecastings            | 35% |
| Desulfurization        | 16% |
| Others such as anodes  | 9%  |
| Organic synthesis, etc |     |

Magnesium is employed in a wide variety of applications based on its chemical, electrochemical, physical, and mechanical properties. Aluminum alloying is the largest application, accounting for over the half of total world consumption. Relatively small additions of magnesium to aluminum improve its strength and corrosion resistance. Most popular alloys are <alloy 3004> (1.0-1.5 % Mg) used for beverage can bodies, and <alloy 5182> (4.0-5.0 % Mg) used for the lids. Because of the growing importance of recycling beverage can bodies; an increasing part of this market is conserved each year.

The second most important market is the use of magnesium for structural applications. The main advantage of magnesium with respect to other competing structural metals is its low weight-to-strength ratio. Structural applications include automotive die-casting such as cylinder head covers, clutch housings, wheels, air intake grill, air cleaner covers, transaxle cases and carburetors. The use of magnesium is growing. By the year 2004 the US automobile was using 4.5 kg of magnesium per automobile up from 2.2 kg per automobile a decade ago.

Other growth applications are for die cast parts ranging from lap top computers, luggage frames, lawn mower decks and chain saw housings to baseball bats, fishing reels, etc.

The increasing demands for exotic metals such as Ti, Hf, Zr, Be, U, has also increased demand.

One of the factors in increasing demand of magnesium metal is its parity with Aluminium traditionally it has been the ratio has been 1.7: 1, it has now fallen to 1.07:1 this gives an additional impetus to use magnesium as there can be weight savings without loss of strength.

## Production

Production during the year 2005 is estimated at 610,000 tons and almost 75% is produced in China. The production from China rose from 18% in 1998 to 55% in 2002 and now it is 75% of the world output. The estimated world production for 2003, is 508,000 tons, and for 2004 is 584,000 tons.

## World Wide capacity

| <b>Producer</b>   | <b>Country</b> | <b>Capacity<br/>TPA</b> |
|---|----------------|-------------------------|
| Shanxi Wenxi Baiyu Magnesium Industry Corporation Limited | China          | 15,000                  |
| Shanxi Jishan Huayu (Enterprise) Group Limited            | China          | 36,000                  |
| Ningxia Huayuan Magnesium Corporation                     | China          | 14,000                  |
| China Shanxi XiXin Magnesium industry Co Ltd              | China          | 3,000                   |
| Hebi Jiang hai smelting Co Ltd                            | China          | 18,000                  |
| Minhe Magnesium Factory (MHM)                             | China          | 7,000                   |
| Shanxi Datong Zhongjin Magnesium Industry Company Ltd     | China          | 4,000                   |
| Shanxi Qizhen Magnesium Corporation                       | China          | 8,000                   |
| Shanxi Zhongjin Corporation                               | China          | 7,000                   |
| <b>Total Chinese capacity nearly 400 producers tons</b>   |                | <b>600,000</b>          |
| Dead Sea Magnesium  | Israel         | 35,000                  |
| Solikamsk Magnesia works                                  | CIS            | 18,000                  |
| Avisma,   | CIS            | 20,000                  |
| ZTMK  | Ukraine        | 5,000                   |
| UKTMK   | Khazhakstan    | 10,000                  |
| Rima Industrial S/A                                       | Brazil         | 6,000                   |
| Bela Stena  | Serbia         | 5,000                   |
| Hydrometal  | Canada         | 53,000                  |
| Magcorp   | USA            | 45,000                  |
| Rest of the world   |                | <b>197,000</b>          |
| <b>Total for year ending 2005</b>                         |                | <b>797,000</b>          |

## Status of Current Projects

| <b>Company</b>                                 | <b>Country</b> | <b>Capacity</b> | <b>Remarks</b>                    |
|--|----------------|-----------------|-----------------------------------|
| Australian Magnesium Corporation Limited (AMC) | Australia      | 95,000          | Abandoned \$575 million write off |
| Indcor Limited                                 | Australia      |                 | No progress                       |
| Latrobe Magnesium                              | Australia      | 100000          | No progress                       |
| Magnesium International Limited (MIL)          | Australia      | 84,000          | Shifted to Egypt now MIL/EMAG     |
| New World Alloys Limited                       | Australia      |                 | Shifting to Malaysia              |
| Commerce Venture Manufacturing Sdn Bhd         | Malaysia       | 15000           | Financial closure                 |
| Pacific Magnesium Corporation Limited          | Australia      |                 | No progress                       |
| Leader mining /Cogburn                         | Canada         |                 | Study stage                       |
| Mag Industries Corp                            | Congo          | 60,000          | Construction start 2007           |
| MIL/EMAG                                       | Egypt          | 43,000          | 2008                              |
| EMAC/Al-kharafi                                | Egypt          | 20,000          | 2009/10                           |

At one time eight magnesium projects were being planned in Australia two have shifted and others have shown no progress although they are not officially abandoned having spent millions of dollars in preliminary assessment.

MIL/EMAG found the capex was too high after detailed study by Ferrostahl. The capex is being reworked with greater sourcing of equipment from Egypt and India, it also exploring the possibility of mining magnesite in Egypt instead of importing it from Myrtle Springs, Australia, which is the current plan.

The EMAC project promoted by Al-Kharafi group of Kuwait is based on recovery of magnesium chloride from Lake Qarun and is part of \$600 million investment in a project to protect Lake Qarun.

Magcorp, USA survived for two reasons it made vast improvements in the technology of production of magnesium chloride feed and cell productivity, and secondly due to imposition of antidumping duties of up to 141.49% on Chinese product and varying rates for products from other countries.

Mag Ind Corp Congo project is tied up with two other projects of hydro electricity and potash mining

Dow chemicals, the inventor of what is known as Dow process closed down after nearly 60 years, and sold the technology to MIL/EMAG. Norsk Hydro in Norway shut down in 2002; the last magnesium producer in Europe. Norsk hydro the operator of the sole plant in Canada is likely to make an exit from the magnesium business in the near future.

USGS 2004 report mentions a production of 570.000 tons world wide

The world consumption of magnesium was approx 332,000 in 1993 and is slated to grow to more than 580,000 tons by 2005 and to 700,000 tons by 2007.

| Year | Die casting | Desulphurization | Aluminium alloying | Total   |
|------|-------------|------------------|--------------------|---------|
| 1995 | 62,500      | 36,000           | 157,000            | 255,500 |
| 1996 | 72,300      | 39,000           | 138,200            | 249,500 |
| 1997 | 95,300      | 47,950           | 146,300            | 289,550 |
| 1998 | 110,300     | 48,300           | 154,000            | 312,600 |
| 2005 | 292,900     | 160,000          | 189,400            | 642,300 |

## Chinese competition

The result is nearly 400 manufacturers came up. A large number of plants produce little more than 1000 tons per annum, they are the first to be affected if there is dip in prices. All this would not have happened without deliberate intervention by the Chinese Authorities and their calculated farsightedness in creating a situation where the industry would grow and ultimately dominate the world market. After the initial rush in China the plants are now becoming more energy efficient and other sources of by-product energy such as coke oven gases are being employed. The margins are now not that high as the prices of ferro-silicon have arisen. This has only dampened the rate expansion of existing units or temporary closure of the smallest of units.

One of the problems with Chinese suppliers that has emerged is reliability of contracts. An analyst with knowledge of Chinese producers and markets has to say this.

"Chinese supply is proving less reliable than it has been in previous years,"

"Ferro-silicon, which the Pidgeon Process relies on as a reducing agent, has become costly and difficult to source and expensive in China and is one of the key drivers of production costs," It is also pointed out the price increases may not be materials based only.

"It is believed non-Chinese capacity must be built to offset the country risk."

"Large magnesium consumers need surety of supply, so we believe an opportunity exists for a reliable country such as Australia to become a primary producer to offset that risk."

"However, this can only occur if countries are fully cost competitive with China, have commercially proven technology, and an off take agreement to ensure cash flow for financing a new project." This was in beginning 2005

The current situation is, ferrosilicon continuous to be available at increased but competitive price, Chinese players have emerged, some of them with tie up with western companies, to provide reliable supplies. Number of smaller units have closed down may be 40-50 but others have expanded. The Chinese Govt has also imposed an export duty.



## Price

The entry of ferrosilicon based Chinese metal has had a significant impact on the prices the prices has once dipped down to as low as \$ 1300 per ton. This has forced the closure of existing producers in the western countries. The sole US producer has won a reprieve as antidumping duties have been levied very recently on Chinese and Russian products.

The prices have since moved up and the latest prices are approx. \$ 1750 FOB China. The exports from China are indicative of prices close to the above ranging from \$ 1790 to \$ 2050 per ton CIF India in the last one year. International prices are quoted at \$ 1850.

The prices have tended to follow the price of ferrosilicon . About 2 tons of ferrosilicon are needed for in ton of magnesium. It is interesting to note that magnesium prices have not followed the trends in prices of aluminium, copper, zinc, etc.

## A Window of Opportunity

The inverse price differential that has happened vis-à-vis aluminium offers an opportunity to reduce costs as well as weight of finished products. All laptops can be offered with lower case weight instead of select ones. Higher magnesium content alloys can be tried in many products. Already Chinese companies are enlarging the market by offering magnesium bicycles and motor cycles, advantage lower weight, greater mileage. A magnesium based bicycle can probably weigh about 9 kg. There is no technical reasons why the magnesium content of cars cannot be raised to say 15-20 kg per car from the current 4-5 kg. As usual the Indian industry has still to wake up to the benefits of lower priced magnesium in terms of consumer or industrial product offerings.

## Acknowledgement

Most of the information on processes is from company brochures or handouts, USGS services and public sources.