Magnesium Production Methods — Raw Materials and Availability

Our purpose herewith is to offer a concise presentation of the raw materials used in magnesium production, the various processes of operation as well as existing production capacities. Magnesium, a light metal, is often opposed to aluminum, another light metal whose density is however once and a half greater. These metals, given as competing ones, nevertheless offer a common positive synergy, that is, the development of aluminum alloys containing magnesium is faster than the primary aluminum production. These metals, given as competing ones, nevertheless offer a common positive synergy, that is, the development of aluminum alloys containing magnesium is faster than the primary aluminum production.

### Raw Materials

Whereas magnesium is not naturally present in the metallic form, it is on the other hand abundant in the shape of 150 combinations. Magnesium average content in the earth crust is 2%. It ranks number 8 among constituent elements thereof, and number 3 among metals, after iron and aluminum.

Magnesium is contained in sea water in a non-negligible proportion, namely, 1.3 kg/m³ as chloride. Sea water constitutes an inexhaustible source about which it was once written that working on 1% only of its reserves would allow the production of 20 million Tonnes/year for 10 million years. This is fabulous: Such resources are unique and same does not exist for other metals.

Another important ore is dolomite, a double magnesium and calcium carbonate. Dolomite can be found everywhere in the world.

The abundance and geographical distribution of these resources might therefore enable any country with appropriate technology and fairly cheap energy available to develop an independent magnesium production industry.

This is one of the major assets of magnesium, whereby the growing interest in aluminum, there is no dependence on some ore, the deposits of which are located in strictly determined geographical areas.

Main magnesium sources used in industrial production are as follows. (Fig. 1):

1. **Giobertite or Magnesite.** Some deposits exist in the United States, Manchuria, India, USSR, Yugoslavia, Greece and Austria.
2. **Dolomite.** Dolomite is far more widely spread than giobertite, but its magnesium oxide content is only half as much. It is to be found in nearly every country, especially in France, Italy, Germany and Great Britain, only to mention EEC countries. **Carnallite.** Carnallite is a double magnesium and potassium chloride treated in USSR.
3. **Sea Water and certain Lake Water.** Such waters are being treated in the USA and Norway.

Other raw materials used in the manufacturing then the refining of magnesium and called "consumables" are in no way different from those used in other electro-metallurgical productions.

Most of the refining agents are also by-products issued from other chemical or electro-metallurgical productions.

### Production Processes

Production processes can be sorted into two very different operation channels, which is easily understandable when referring to the two major ore categories:

1. **Electrolytic Reduction of Magnesium Chloride From: Brine origin**
2. **Thermic Reduction of Magnesium Oxide**

Calcined dolomite. The reducing agent is mostly ferro-silicon 75%, and sometimes aluminum when low cost aluminum scrap is available.

We are now going to briefly describe the different processes in operation at the present time.

1. **Electrolytic Processes**
   - **Dow Process** (Fig. 2)
     - Raw materials consist of sea water and dolomite. The main stages of the process are as follows:
       - Calculation of dolomite
       - Precipitation of magnesium hydrates
       - Chlorination of hydrates by hydrochloric acid
       - Refining and concentration of magnesium chloride
       - Electrolysis of hydrous magnesium chloride
   - The chlorine obtained during the electrolysis is partly used for the production of hydrochloric acid while the remnant is liquified.

   - **Norsk Hydro Process** (Fig. 3)
     - Raw materials are also sea water and dolomite or brines with a high content of MgCl₂.
     - The process differs from the one above in that hydroxides are calcined. After pelletization with coke, the oxide thus obtained is then converted into magnesium chloride by using the chlorine of electrolytic cells. (1) It is to be noted that chloride feed from either source is fully dehydrated before entering the electrolytic cells.

   - **Amax (ex-N. L. Industries) Process** (Fig. 4)
     - Raw materials are brines from the Great Salt Lake concentrated in solar ponds. They get further concentrated, refined and dehydrated prior to electrolysis.
     - Electrolytic processes also permit the production of chlorine and other by-products (salts contained in sea water and brines)

2. **Thermic Processes**
   - **Pidgeon Process** (Fig. 5)
     - Raw materials usually consist of dolomite, the reducing agent being ferro-silicon. Dolomite and ferro-silicon briquettes are heated externally

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up to a temperature of 1100°C, the retorts being kept under high vacuum.

The operation residue is a solid slag.

Many improvements have been brought to this process since 1940 with a view to increasing its productivity. It is being used in Canada and Japan.

b. **Bolzano Process** (Fig. 6)

This process was derived from the Pidgeon Process. The dimensions of the retorts are larger. Their electrical heating is internal. The by-product is a magnesia and lime silicate.

The raw materials used in the Bolzano Process are the same ones as those of the Pidgeon Process. However, the feeding apparatus, the furnace shape and the recovering operation of products and by-products are entirely different.

Briquettes of mixed dolomite and ferro-silicon are introduced into an electrically heated furnace under vacuum. The magnesium is reduced and condensed in the solid form every day as a block of 2000 kg or more.

This process has been developed and is operated by SAIM in Italy.

c. **Magnetherm Process** (Fig. 7)

The Magnetherm Process also consists in the reduction of calcined dolomite by ferro-silicon, without any previous briquetting.

The reduction is achieved in a tight electrical furnace, under reduced pressure and at a temperature of 1600°C, a temperature definitely higher than in the Bolzano Process.

Through the addition of a fluidizing agent, alumina, a liquid slag is obtained. By-products are therefore this slag, which is used in cement works and some low grade ferro-silicon used as thermic load in steel works.

This process is used in SOFREM in France and its licensees in the USA and Yugoslavia.

Both types of process are actually very different, since electrolytic processes are related to the chemical industry while thermic processes are connected with electremetallurgy.

One of the consequences deriving from this bears on installation capacities. Electrolytic processes only pay when operating high capacities of more than 15,000 Tonnes/year. Thermic processes are more flexible and can accommodate capacities lower than 500 Tonnes/year.

**Availability of Primary Magnesium**

The present situation regarding production capacity is summarized in Fig. 8.

**Magnesium Production Evolution**

The recent evolution of primary magnesium production appears clearly from IMA Statistics for the Western World as shown in Fig. 9.

Considering only the total figures worldwide we see:

- An average annual rate of growth of +28%
6% over the period 1975-1980
- A peak of production in 1980
- The recession impact on main markets: Capacity utilization was reduced to 77% in 1981 and should be around 70% today.
- The situation in 1982 is characterized by an increase in producers' inventories which has been estimated to be around 90,000 tonnes, that is, more than 4 months' production.
- A fast growing demand can therefore be met. On the other hand, capacity rises through alterations to existing facilities are under way, whereas a great many new projects are under study.

Economic Considerations (Fig. 20)
Magnesium production plants are rather different from one another according to their type of process, their size, and the higher or lower level of product integration and diversification.
The performances of the various products can therefore hardly be compared with regard to production and capital costs.
Endeavours are made by most producers, through technological improvements carried out at every processing stage, in order to reduce the global energy consumption which remains an essential component of production cost.
It is generally granted that the global energy consumption required for the production of 1 Kg of magnesium ingots from raw materials lies within the following amounts:
- 28 to 40 Kilowatt hours of electrical energy or equivalent, or
- 240 to 350 Megajoules of thermal energy.
It is obvious that modern magnesium production units are on the lower side of the range.
The above energy cost on a weight basis is nevertheless only 15 to 20% higher than the equivalent cost for aluminum.
Magnesium

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production, should the whole process line, from ore to primary ingot be taken into consideration: On a volume basis, magnesium requires far less energy than aluminum. With regard to investments, installed capacities differ also in large proportions, from 5 to 100,000 tonnes/year. magnesium presents an attractive weight and cost reducing alternative to aluminum. Under normal business conditions, magnesium presents an attractive weight and cost reducing alternative to aluminum.

Primary Aluminum Production

Primary Aluminum production* as reported by IPAl Members** was 845 thousands of metric tons in October 1982 compared with the 1014 thousands of metric tons produced in October 1981, the International Primary Aluminum Institute reported.

AREA ANALYSIS AS REPORTED TO IPAl

| AREA | NORTH AMERICA | SOUTH AMERICA | EUR. | EUROPE | OCEANIA | TOTAL
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<td>5603</td>
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<td>817</td>
<td>513</td>
<td>3551</td>
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<tr>
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<td>4757</td>
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<td>3672</td>
<td>656</td>
<td>329</td>
<td>511</td>
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Production of primary aluminum is defined as the weight of liquid aluminum as tapped from the pots excluding alloying elements, returned scrap or remelted products. Units are metric tons rounded to the nearest one thousand tons.

Primary Production Rate Down 30.4 Per Cent

U.S. primary aluminum production averaged 8,880 short tons daily during October, 1982 compared with an average 12,760 tons a day in October, 1981. The annual rate of production in October, 1982 was 3,241,159 tons, compared to 4,657,453 tons in October, 1981. The September, 1982 production rate was 3,298,955 tons.

Actual production in October, 1982 was 271,277 tons, compared with 271,147 tons in September, 1982.