AT VEENDAM, in north-east Netherlands, Nedmag Industries Mining & Manufacturing BV owns a magnesia operation somewhat unique amongst producers. Nedmag sources its magnesia by solution mining magnesium chloride deposits (bischofite/carnallite) of the Zechstein basin some 2km below the surface.

From this rich source, which yields about 500,000 tpa of raw magnesium-rich salts, Nedmag produces a suite of products including dead burned magnesia (DBM), caustic calcined magnesia (CCM), magnesium chloride, magnesium hydroxide, and calcium chloride. However, Nedmag has come a long way from its start-up as a DBM-only producer.

**Nedmag annual production (tonnes)**

<table>
<thead>
<tr>
<th>Product</th>
<th>Annual Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBM</td>
<td>153,000</td>
</tr>
<tr>
<td>CCM</td>
<td>6,000 bulk, 1,000 bags</td>
</tr>
<tr>
<td>MgCl₂</td>
<td>40,000 flakes; 41,000 liquid (100% basis)</td>
</tr>
<tr>
<td>Mg(OH)₂</td>
<td>4,000 (100% basis)</td>
</tr>
<tr>
<td>CaCl₂</td>
<td>25,000 prills, 22,000 liquid (100% basis)</td>
</tr>
</tbody>
</table>

**History**

During the course of exploratory drilling for gas in the Groningen area, north of the Netherlands, Royal Dutch/Shell encountered a layer of the magnesium chloride minerals, bischofite and carnallite. This unexpected discovery of a unique bischofite deposit provided the incentive for a new venture. In 1979, Shell formed a joint venture between subsidiary Billiton Nederland BV and NV Noordelijke Ontwikkelings Maatschappij (NOM), a Dutch Investment Bank, called Magnesia International (Magin), to produce dead burned magnesia, which started in 1981. An associate company, Noordelijke Zoutwinning BV (NOZO) was responsible for the mining of the magnesium salts (see panel).

In 1987, Magin and NOZO merged into Billiton Refractories BV, wholly owned by Billiton Nederland BV, and ultimately owned by Shell Petroleum BV.

In 1994, the company passed into the hands of a new group of shareholders, and was renamed Nedmag Industries Mining and Manufacturing BV, in which Nedmag stands for Nederlandse Magnesia. The ownership is NOM, 47%, Lhoist Group, 47%, management, 6%.

However, since its start-up in 1981, market trends, especially with regard to DBM use in refractories, influenced Nedmag’s business plans and ultimately necessitated a major strategy review in the mid-1990s.

**Strategic review**

Initially, Nedmag’s prime focus was solely on DBM production, but by 1993 the company realised the need to implement a major change in strategy. Nedmag refocused its DBM production and marketing, and diversified.

In the late 1980s to early 1990s, Nedmag’s DBM (nedMag99) was mostly aimed at the magnesia-carbon refractory brick market for the iron and steel industry. However, towards the end of that period, Nedmag started to serve the magnesia-spinel refractory brick market. This market had largely arisen from the need to replace chromite-bearing bricks in cement kilns (owing to their post-use hazard to the environment with Cr⁶⁺) with an alternative refractory product, ie. mag-spinel.

Nedmag’s response to market changes has ensured its survival as a leading producer of DBM while diversifying its product portfolio.

At the same time, there was a change in emphasis from steelmakers to produce alternative low carbon quality steel (thus less mag-carbon brick use), and increased competition in magnesia supply for mag-carbon bricks from lower cost sources of DBM, and increasingly fused magnesia (as a DBM substitute) from China.

In Nedmag’s view, there appeared only one option to take, “to tackle fixed costs per metric tonne” of DBM. To achieve this, Nedmag took steps to increase production by utilisation of extra capacity, a company-wide strategic quality plan, and a new marketing approach.

Nedmag felt the need to change its whole concept from one of being a niche market layer, to a “leading producer”. To this end the company set out to explore the potential of long term
relationships with the main strategic customers and identify new geographic regions not previously considered for sales.

It was already clear that DBM production capacity and consumption was in decline. During 1992, total DBM world production capacity was some 1.8m. tpa. Since that time, there have been a series of high profile exits by players from the DBM supply market, and by 2004 world production capacity had dropped by 66% to around 600,000 tpa.

Nedmag’s sales of DBM to mag-spinel bricks have increased from 60,000 tonnes in 1993, to almost 120,000 tonnes in 2004. While sales to mag-carbon peaked in 1999 with about 50,000 tonnes, they have dropped to less than 40,000 tonnes in 2004.

In addition to refocusing its DBM marketing, Nedmag sought to diversify its product portfolio on the basis of its raw material source, ie. magnesium chloride, to produce magnesium chloride and calcium chloride grades. In 1993, Nedmag further developed its MgCl₂ production. As of 1996 they successfully managed to convince the market to take MgCl₂ flakes besides liquid.

In 2001, Nedmag secured its CaCl₂ production facilities through the acquisition of the on-site calcium chloride activities of Kappe Intermediair and Kareva BV, thus complementing Nedmag’s salt business.

Prior to 1993, 100% of the company’s turnover represented DBM production, but today that figure has reduced to 75% for DBM, with the remainder being MgCl₂, 11%, CaCl₂, 10%, CCM, 3%, Mg(OH)₂, 1%.

Markets

Nedmag’s DBM grade (nedMag 99) is mostly consumed by producers of magnesia-spinel refractories (about 80% of output) for mostly cement kiln applications, while the remainder is used in other magnesia-based steel refractories such as mag-carbon, mag-dolomite, and magnesite bricks.

CCM (nedMag 99) serves a range of markets including, spinel manufacture, printing inks, cements, fertilisers, feed additives, water treatment products, polymers, pulp and paper, and sugar.

Markets for CaCl₂ (nedMag Ca) include de-icing, dust suppression, oil and gas exploration, and other industrial applications. Some CaCl₂ is shipped to North America for de-icing and de-dusting applications.

Nedmag’s MgCl₂ flakes are exported as far afield as New Zealand. Market applications for MgCl₂ (nedMag C) include de-icing, dust suppression, Sorel cement flooring, grinding & polishing stones, and animal feed.

Calcium chloride product in big bags awaits shipment from Veendam. Some goes as far North America for the de-icing market.

Above: Production of MgCl₂ flakes. Markets include de-icing, dust suppression, Sorel cement flooring, grinding & polishing stones, and animal feed.

Below: Looking towards the adjacent operation of Kisuma Chemicals from Nedmag’s plant. Kisuma is the European affiliate of Japanese flame retardant leader Kyowa Chemical Industry Co. Ltd. It receives MgCl₂ flake feedstock from Nedmag.

<table>
<thead>
<tr>
<th>Nedmag projected production volumes 2007 (tonnes)</th>
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<tbody>
<tr>
<td><strong>DBM/CCM</strong></td>
</tr>
<tr>
<td><strong>MgCl₂</strong></td>
</tr>
<tr>
<td><strong>Mg(OH)₂</strong></td>
</tr>
<tr>
<td><strong>CaCl₂</strong></td>
</tr>
</tbody>
</table>
Nedmag’s process route

Solution mining
Magnesium chloride salts are extracted from a depth of approximately 1,500 metres. By a modern solution mining technique, these salts are dissolved by introducing water under high pressure, after which the formed concentrated brine (>30% magnesium chloride) is pressed upwards. This crude brine is sold as nedMag®-SQ (Standard quality).

Purification
For some applications, extra purification of the magnesium chloride brine is required. By means of an active coal filter undissolved iron is removed, resulting in nedMag C - FQ (filtered quality). Further purification is achieved by oxidation of the dissolved iron into Fe(III) precipitate followed by membrane filtration and an additional active coal filtration, giving nedMag C - PQ.

Flaking
The magnesium chloride can be provided in a solid form as well. For this purpose the brine is heated to get a saturated solution of 47% magnesium chloride. This hot concentrated liquid is then transported to a water cooled rotating drum, where solid magnesium chloride flakes are formed: nedMag C - flakes.

Boron removal
Crude magnesium chloride brine for MgO production is treated in an ion exchanger for boron removal. The boron selective resin is regenerated with hydrochloric acid. Subsequently the sulphate in the brine is reduced by using calcium chloride brine, the gypsum precipitate CaSO4.2H2O formed is thickened, dewatered on a vacuum beltfilter and disposed of in the MgCl2 caverns from where the raw brine originated. The overflow from the thickener is the purified brine ready for use in the magnesium hydroxide precipitation stage. Both boron and sulphate must be reduced in order to improve the chemical purity of the and refractoriness of the magnesium hydroxide and sintered magnesium oxide respectively.

Dolime slaking
The raw material, solid dolime (CaO.MgO) has to be slaked before it can be used in the process. Slaked dolime is used for the next process step - magnesium hydroxide precipitation. Slaking involves an exothermic hydration reaction of dolime with water,

<table>
<thead>
<tr>
<th>Typical Veendam brine properties</th>
<th>bischofitic brine</th>
<th>carnallitic brine</th>
</tr>
</thead>
<tbody>
<tr>
<td>MgCl2%</td>
<td>32</td>
<td>23</td>
</tr>
<tr>
<td>KCl%</td>
<td>0.3</td>
<td>4.5</td>
</tr>
<tr>
<td>NaCl%</td>
<td>0.4</td>
<td>1.5</td>
</tr>
<tr>
<td>MgSO4%</td>
<td>0.3</td>
<td>1.5</td>
</tr>
<tr>
<td>H2O%</td>
<td>67</td>
<td>68</td>
</tr>
<tr>
<td>density kg/l</td>
<td>1.31</td>
<td>1.27</td>
</tr>
</tbody>
</table>
Maintenance and repair of a shaft kiln at Nedmag. Calcined “green” magnesia briquettes are dead burned in shaft kilns at 2,200°C to produce high purity DBM.

**Precipitation**
The slaked dolime is brought in contact with desulphated magnesium chloride brine. Whereby calcium hydroxide reacts with magnesium chloride to form a magnesium hydroxide precipitate and calcium chloride. The magnesium oxide originating from the slaked dolime will partly hydrate but is still present in the magnesium hydroxide precipitate. The spent calcium chloride brine is reused in the brine purification process.

**CaCl₂ concentration**
Calcium chloride brine 16% is stored in a 5,000m³ tank as feedstock for the plant and for bulk loading purposes. Sulphate present in the brine must be removed to prevent scale formation in the process stream, by introducing a barium chloride solution to precipitate barium sulphate. Barium sulphate solids are removed in a settler and the 40% is stored in basin and the 55% is the feed for the next stage: prilling.

**Vacuum drum filter**
In three vacuum rotary drum filters, the magnesium suspension is dewatered to form a filter cake with approximately 54% solids. This substance is transported to the next operation stages, the calciners, and the stabilisation process for the production of nedMag H suspension.

**CaCl₂ prilling**
For prills production, hot air is needed, this air is generated in a natural gas burner system where cold atmospheric air is pressed along the burners. The air heater produces air with a temperature of 480°C, which after passing the prilling tower is dedusted in a cyclone and a wet scrubbing system. In a fluid bed granulation tower 55% solution is further concentrated with hot air to a approx. 3 mm granulated particle with 96% CaCl₂. These so called “green” prills are sieved and fed into the shaft kilns for sintering or supplied as nedMag 99 Caustic Briquettes.

**Sintering**
The green briquettes are sintered (dead burned) in a shaft kiln with an oval shaped cross section. The residence time in the shaft kiln, is controlled by a drag bar, a moving beam on a table, that removes the product from the kiln. By means of natural gas / air burners a temperature of up to 2,200°C is reached, to produce dense high purity dead burned magnesia: nedMag 99 Briquettes.

**Washing**
The slurry, containing magnesium hydroxide solids and solved calcium chloride, is washed countercurrently to remove all chlorides. During this process a flocculant is added to improve the settling and compaction behaviour of the magnesium hydroxide.

**Grinding & milling**
nedMag 99 -DBM Briquettes are used as feedstock in the grinding and milling process. Firstly the briquettes are crushed below a size of 6mm. This product can be sieved in one or two steps to the various required fractions or fed into a ball mill where it can be sized down to various mesh sizes. The different sizes are packed either in 1,000kg bigbags or in 25kg paper bags both with polyethylene-inliners if required.