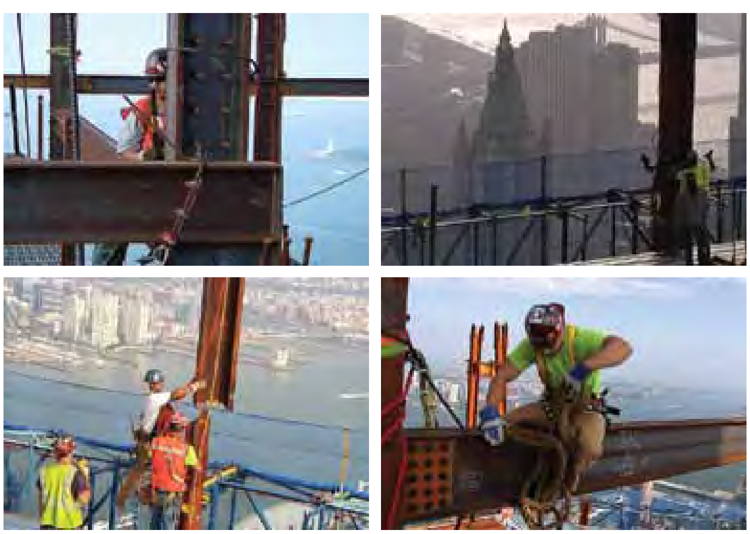
Desulfurizing Steel:
Magnesium is the Reagent of Choice

In the process of steelmaking, removing excess sulfur from the hot metal is key to creating high-quality structural steel. Why control sulfur content? In many applications, sulfur content control is critical, since sulfur in the form of iron sulfides (FeS) can lead to structural failure. Steel mills use a variety of materials and technologies to remove sulfur from steel, because structural steel applications demand low sulfur levels in order to achieve the highest quality structural steel, with optimal strength, forming and joining characteristics.

Sulfur, present in solid steel as FeS inclusions, has several detrimental effects on steel processing and on steel's physical properties. During deformation, the FeS inclusions act as crack initiation sites and zones of weakness. Such inclusions from sulfur adversely affect steel's toughness, ductility, formability, weldability, and corrosion resistance. An increase in manganese however, will help prevent formation of FeS, which is highly detrimental to steel's hot workability and also leads to severe cracking. Sulfur is such an undesirable element in structural steel that its removal is desired.

Construction of One World Trade Center in Lower Manhattan, New York City, USA, uses 45,000 U.S. tons of high-strength structural steel. At 1,760 feet tall, the 104-floor superstructure will now be the tallest building in the Western Hemisphere. © Photo courtesy of The Port Authority of New York & New Jersey. Used with permission.

Steelmakers rely on magnesium reagents to produce the top-quality steel demanded by the building industry for such structures as One World Trade Center, now under construction in New York City. The building uses 45,000 U.S. tons of structural steel, with floors erected at the rate of one floor per week. When "topping out" – when the last steel beam is put in place there will be 104 floors topped with a massive spire. Upon its completion, the 1,760-foot-tall structure will be the tallest building in the Western Hemisphere.



The anticipated Leadership in Energy and Environmental Design (LEED) Gold structure's design incorporates a redundant steel moment frame consisting of welded and bolted steel beams and columns. The steel is combined with a concrete-core shear wall and a glass and stainless steel façade skin in an angled design with a spire at its peak, which will house communications equipment. The life-safety systems and sustainable features of One World Trade Center require all construction materials, including the structural steel, to be as strong and durable as possible.

New York City ironworkers install steel beams and perimeter columns fastened with steel bolts on the top deck of the new One World Trade Center. © Photos courtesy of The Port Authority of New York & New Jersey. Used with permission.

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Treated metal being transferred to converter. © Photo courtesy of Almamet GnbH. Used with permission.

Desulfurized Iron is Converted into Quality Structural Steel

The use of magnesium in advanced desulfurization methods and specialized equipment for hot metal desulfurization has been developed by companies such as Almamet GmbH, Ainring, Germany. Almamet has developed innovative handling and transport methods and improved the injection process by collaborating with injection equipment designers and suppliers. Almamet delivers high-quality injection lances for steel production that are designed for the smooth injection of solids and gases into the iron melt, to improve process efficiency.

Lance removal taking place during the desulfurization process. © Photo courtesy of Almamet GmbH. Used with permission.

The lance is inserted into the ladle, for injection of magnesium reagent material. © Photo courtesy of Almamet GmbH. Used with permission.

According to Almamet, when producing high-quality structural steel, magnesium reagent is an important material used to desulfurize hot metal during the steelmaking process, along with calcium-carbide and high-grade injectable lime. Of these three, magnesium gives the best low sulfur level results. To best satisfy low sulfur requirements for turning iron into steel, Almamet's process injects magnesium reagents in powder or granular form into the ladle to remove sulfur, which is converted into the ladle slag top, and is then removed by dragging the thicker formed top layer from the newly-processed sulfur-free metal in the ladle via slag top removal.

According to Almamet, typically when iron is received from blast furnaces, its sulfur content ranges from 0.025 percent to 0.050 percent. To produce high-quality structural steels, most steel mills require final sulfur levels at or below 0.002 percent prior to charging into the converters and further treatment. In addition to providing "prime" magnesium additions to remove sulfur from iron, Almamet has developed processes that allow various grades of magnesium scrap to be used successfully in the desulfurization process, allowing die casters and others who use magnesium alloys a way to reuse and recycle their magnesium scrap.

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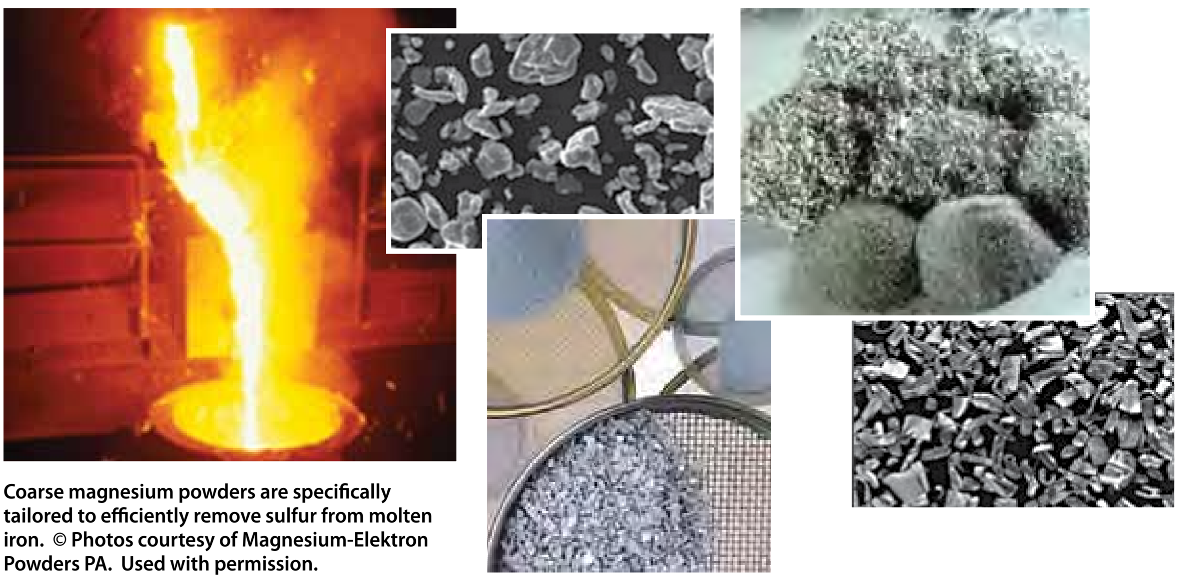
Magnesium Reagent Delivers the Lowest Sulfur Content

According to Mark Borsody, Sales Manager at Magnesium-Elektron Powders PA, Tamaqua, Pennsylvania, steel manufacturers reduce sulfur content during pretreatment of the molten iron. He explains, "Integrated steel mills have a smelting vessel (blast furnace) and a steel conversion vessel called a basic oxygen furnace (BOF). Iron ore, limestone and coke are added to the blast furnace and heated to very high temperatures. Once heated, bi-products (liquid and gas) are diverted from the liquid iron. The hot metal is poured into a vessel, transported by rail to the BOF facility, poured into a transfer ladle, desulfurized, and then poured into the BOF to convert from iron into steel."

Borsody agrees that in order to blend high-quality structural steel, magnesium reagent is the material of choice for the desulfurization of hot metal during the steelmaking process. To satisfy low sulfur requirements for iron processed into steel, magnesium reagents in powder or granular form are used to remove sulfur via slag-liquid metal reactions done under reducing conditions, where sulfur is transferred out of the steel through the slag-metal interface, and into the slag. Slag is an ionic solution made up of oxides and fluxes.

"Magnesium is by far the preferred reagent option for its optimal speed and efficiency in removing sulfur from iron, and also due to the substantially higher yield of quality steel realized using magnesium reagent, since far less iron makes its way into the resultant slag, compared to other reagents," says Borsody, "Using magnesium reagent to desulfurize iron results in a higher tensile strength steel that makes thinner lighter automotive steel, far stronger construction steel, and a much more wear-resistant deep well drilling steel for oil and gas drilling. Hot metal desulfurization with magnesium has proven to be the optimum solution for sulfur control during steelmaking."



Coarse magnesium powders are specifically tailored to efficiently remove sulfur from molten iron. © Photos courtesy of Magnesium-Elektron Powders PA. Used with permission.

Borsody describes the mechanics of sulfur removal: "The desulfurization process takes place in an iron transfer ladle. The primary magnesium reagent is injected in conjunction with a secondary reagent, usually lime, into the hot metal with lances under a gases stream. The lance is a pipe surrounded by several inches of protective ceramics. When injection is completed, thick slag is formed at the top of the ladle containing magnesium sulfides that have levitated through and become attached to the hot metal. Sulfur-saturated slag is then mechanically raked (skimmed) from the top of the transfer ladle and the desulfurized iron is then introduced into the BOF."

"Hot metal in the transfer ladle is in liquid form, while most other elements in the ladle are in a gaseous state," Borsody continues, "The higher the hot metal temperature, the lower the metal's specific gravity; lower hot metal viscosity allows for easier levitation of the magnesium sulfite gas to the slag, removing the optimal amount of sulfur from the iron. When the magnesium attaches to the sulfur they are both in gaseous form, since magnesium's boiling point is 1994°F, and the boiling point for sulfur is 832°F."

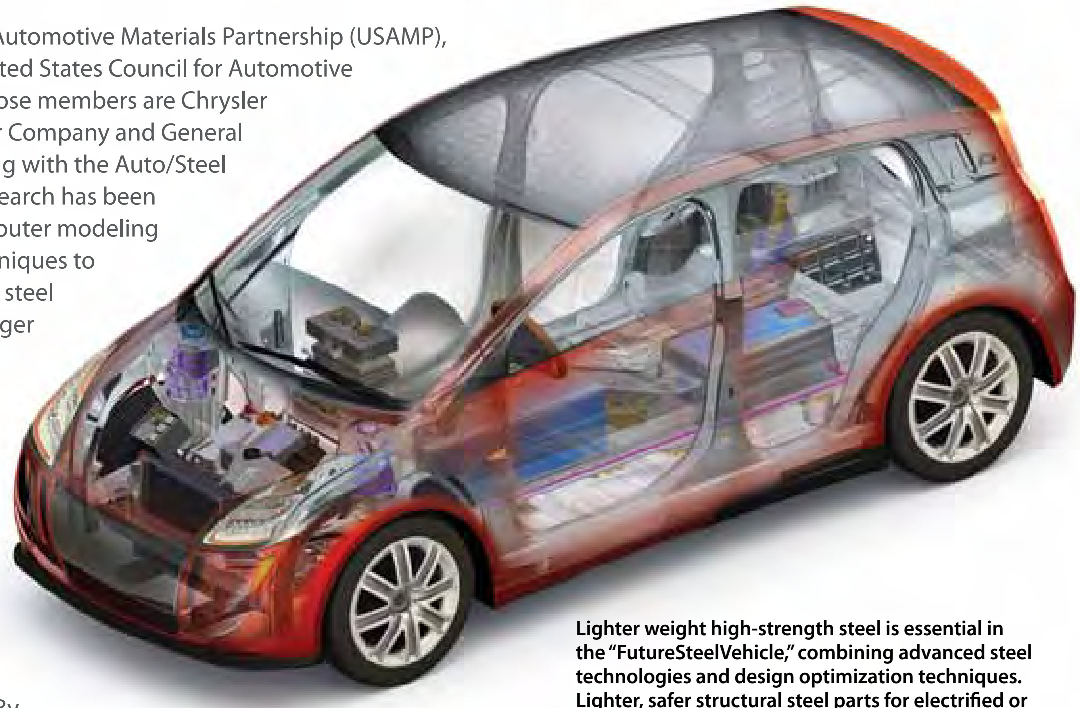
Steel producers must meet stringent structural and environmental standards, while maximizing yield of the highest quality steel possible. Steelmakers turn to magnesium for desulfurization because, according to Magnesium Elektron, Manchester, England, magnesium has a high chemical affinity for sulfur and dissolves in the iron-carbon melt, which causes the magnesium reaction with sulfur to produce homogeneous material. Magnesium reagents used in desulfurization are cost-effective, environmentally friendly and recyclable, and deliver low slag generation, low iron losses in the slag, and achievable final sulfur levels in the steel below 0.002 percent.

ESM Group Inc., Amherst, New York, also provides magnesium reagents for steelmaking. In addition to magnesium reagents, ESM Group offers specially-designed injection equipment, bulk material handling and storage, and programmable logic control (PLC) instrumentation for co-injecting magnesium with lime or calcium-carbide reagents. Their co-injection system introduces magnesium and other powdered reagents simultaneously into torpedo or open transfer ladles using precision-controlled and monitored injection to reduce sulfur to desired levels, optimizing performance efficiency and reducing costs.

ESM's PLC continuously monitors system variables including weight, pressure and flow rate, making on-the-spot adjustments. All programming is done in-house by ESM software engineers, which results in a system that meets each customer's specific requirements. © Photo courtesy of ESM Group Inc. Used with permission.

Data collected from ESM's PLC reports performance data from thousands of desulfurized heats each month and provides real-time electronic feedback to customers. This control system eliminates unnecessary overtreatment, reduces costs, and optimizes process efficiency by recognizing the steelmaker's unique application, logistics, and processes.

According to the U.S. Automotive Materials Partnership (USAMP), a subsidiary of the United States Council for Automotive Research (USCAR), whose members are Chrysler Group LLC, Ford Motor Company and General Motors Company, along with the Auto/Steel Partnership (A/SP), research has been conducted using computer modeling and optimization techniques to validate high-strength steel parts for use in passenger compartments in four-door, five-passenger sedans. This example of another demanding application for high-quality steel simulates how transverse steel tube directly absorbs side impact forces within the front seat. By using high-strength steel for this application, lower mass and weight are achieved without compromising the passenger compartment's structural integrity or crashworthiness. High-grade steel requires desulfurization, and magnesium reagent best achieves this quality level. Strategic placement of advanced, high-grade steels will be integral to lightweight vehicles in the future, and to maintaining safety while facilitating vehicle fuel economy.



Lighter weight high-strength steel is essential in the "FutureSteelVehicle," combining advanced steel technologies and design optimization techniques. Lighter, safer structural steel parts for electrified or internal combustion engine vehicles reduce emissions over the vehicle's life cycle. © Photo courtesy of the Steel Market Development Institute. Used with permission.

Magnesium has proven essential to the steelmaking process, and desulfurization techniques continue to improve as systems and process technologies develop and advance. Magnesium and magnesium alloy granules and powders are blended into reagents that are designed to achieve consistent results when preparing iron for steelmaking. Companies that make magnesium reagents must meet standards as strict as those met by the steelmakers who use them.

The desulfurization process in the iron melt ensures that steel not only has maximum structural strength and high performance, but optimum corrosion resistance over time. To achieve these results, magnesium has become the go-to reagent material for steelmakers who forge their livelihoods and their reputations on making the highest quality product possible.

To learn more about the benefits of designing products with magnesium, contact the
International Magnesium Association
1000 N. Rand Road, Suite 214, Wauconda, IL 60084 USA
Tel. 847.526.2010 • Fax 847.526.3993 • E-mail: info@intlmag.org • www.intlmag.org

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