MAGNESIUM RECYCLING YESTERDAY, TODAY, TOMORROW

Robert E. Brown
Magnesium Monthly Review
226 Deer Trace
Prattville, Alabama 36067, U.S.A.

ABSTRACT

Magnesium recycling has been used to recover both new scrap and old scrap. It was used extensively in Germany during WWII to expand the magnesium supply. There were a large number of magnesium recyclers in the US who got their start smelting old scrap, old airplanes and old waste dumps from the WWII build up. As the world magnesium industry dwindled, only a few companies were left that did magnesium recycling as a primary business. The sand foundries tended to recycle of their production scrap in their melting furnaces. Even the original die casters tended to put scrap directly back into melting furnaces at the die casting machines. As high purity alloys were developed and the use of die castings in automotive work increased, the tendency was to let the magnesium recyclers convert the scrap back to high quality ingot. Automotive use has grown because of the low density of magnesium. This property is the one of the biggest problems to overcome in shipping scrap. Gates and runners from die casting are very irregular shapes and it is very hard to load a truck with enough material to get a low shipping cost per pound. Recent new equipment companies have developed magnesium equipment that is specifically designed to recycle, refine and cast secondary magnesium metal. These melt cells are supplied as integrated units to magnesium casting sites. The cost and effectiveness of this approach will be discussed.
INTRODUCTION

Recycling and reprocessing of many materials is constantly being emphasized in most areas of the civilized world. North America is one of the largest consumers of all types of goods and has long been aware of the economic importance of recycling. In recent years, the environmental aspects of recycling are becoming as large a force as the economic.

This was particularly true in the metals field with the aluminum industry. As more and more aluminum cans came unto the market, recycling was emphasized. It was both economic and environmental. The recycling of the can alloy which had a high magnesium content, meant recovering aluminum alloy which is expensive to produce.

As magnesium usage continues to increase, the economic and environmental pressures will continue to increase in this industry. The increasing use of magnesium die castings in vehicles is an indirect result of environmental pressure being brought to bear on the automotive industry. The new Corporate Average Fuel Economy (CAFE) program is designed to require vehicles to use less gasoline and create less atmospheric pollution. Magnesium is being used to replace heavier materials to enable the car size to be maintained while increasing the average miles per gallons. The present mileage program calls for fleets of cars (Same manufacturers model, such as Chevy Chevelle) to demonstrate that they can get 27.5 miles per gallon of gas. There are plans to increase the standard to 30 miles per gallon. A gradual increase was called for in the original bill, but it has been stabilized at 27.5 mpg by lobbying and reluctance of legislators to insist that the original goals be reestablished due to the cheap gas prices.

The Clinton administration announced in December 1999 that the US Environmental Protection Agency (EPA) will soon require Sports Utility Vehicles (SUV), pickup trucks and minivans to meet the same air-pollution standards as passenger cars. By 2007, about 85% of cars and trucks will have to meet the rule. Automakers then will have just two more years to ensure that their largest SUV’s and Pickups – those that weigh between 6,000 and 8,000 pounds- meet the lower emission levels.

U. S. Truck lovers do not want to give up the size of the truck. To keep the size of the truck, reduce emissions and increase fuel economy, the total truck weight must be reduced. Magnesium has been selected for some applications previously and will undoubtedly be the choice for more applications in the future.

HISTORY OF MAGNESIUM RECYCLING

Introduction (1)

The origin of the scrap melting and handling industry in magnesium is somewhat obscured in the literature. The difficulties in getting the magnesium industry started and its small size probably contributed to the lack of scrap coverage.

The problem of melting magnesium, preventing oxidation, and removing any inclusions created many difficulties for the early casting industry. After the development of protective fluxes which contained chlorides, the problem of separating the molten metal from the molten
chlorides played a decisive part in the technical development of magnesium and its alloys for the first 15 years of the industry. The fluxes would protect the molten metal surface from oxidizing and would "wet" the oxide inclusions making them heavier and easier to separate. Until the oxides first, and then the chloride fluxes could be thoroughly separated, it was impossible to use magnesium as a basic metal for construction.

From the year 1922 on there are many patents which cover the melting of and the purifying of magnesium. The rapid increase of the use of magnesium in Germany during the 1930's first identified the use of scrap magnesium. During the war, scrap was only used for castings. It was originally determined by the German industry leaders that primary magnesium should be used for fabricated products.

**Early German Practice**

While I. G. Farbenindustrie was the major magnesium producer in Germany, Wintershall also had a small electrolytic magnesium operation. It was noted in post-war interviews that the alloying practice at the I.G. plants and Wintershall was basically the same. Molten metal was collected from the electrolytic cells in large crane ladles which were taken to either a pigging machine for casting into pure ingot. The metal might also go to the alloying plant for the production of alloy ingot for foundry use or for the production of alloy billets as a preliminary to wrought processing.

At the I.G. plants, which averaged about 3300 tons per month in 1943, production was distributed as follows:

- Cast into pure ingots 600 tons
- Cast into alloy ingots 2000 tons
- Cast into alloy billets 700 tons

Alloy ingot was supplied principally to foundries and I.G. had a virtual monopoly on this business since all foundries had to be licensed under I.G. patents. The I.G. considered this phase of their business to be of utmost importance because the major part of their recovered scrap went into foundry alloys. The impurity limitations on wrought alloys were too stringent to permit the use of secondary metal as a constituent.

The R. L. M. (Reich Luftahrt Ministerium) of Berlin considered the I.G. monopoly in foundry alloys to be abhorrent to the Reich, and attempted to break it through the medium of Wintershall. They did not succeed because the I.G. was too well entrenched in the scrap metal business, and foundry alloy could not be produced competitively using only pure ingot. (Scrap metal was purchased by the I.G. at an average price of around 30 pfkg, compared to a production cost for pure ingot of 1.20-1.30 RM/kg.)

Many of the German foundries segregated their scrap, such as gates and risers keeping each alloy separate. They then re-melted the scrap alloys and poured less critical castings. The process was repeated again, and low quality castings poured from the third melting. This required a great diligence in scrap handling. However, the shortages of magnesium caused by the destruction of the primary production facilities, made the use of scrap a great necessity.
Beck's Comments

Beck (2) said in reference to melting and casting magnesium in a foundry, "In addition to the original ingots, foundry scrap such as runners, risers, and rejects may be added in the proportion in which they occur in the works. It is, however, necessary to clean this casting scrap thoroughly from adhering molding sand, which otherwise would be reduced by the liquid metal and so increase the silicon content of the alloys. Heavily oxidized runners should be cleansed of most of the superficially adhering oxide by sand blasting or by placing in a scouring barrel. They can then be added in small quantities to the normal melts. As a rule, casting scrap should be melted down as soon as possible, since in the course of lengthy storage the casting skin tends to absorb moisture which, similar to oil with which parts rejected by the machining shops are contaminated. For this reason casting scrap which is heavily contaminated, may cause harmful absorption of hydrogen by the metal during re-melting. Casting scrap which is heavily corroded or contaminated with oil should, in addition to receiving the surface cleaning already described, be cast in ingots after melting down. To prevent confusion and alloying errors the various magnesium alloys must be kept separate from each other as well as from aluminum alloys and other non-ferrous metals".

NORTH AMERICAN SCRAP PRACTICE - HISTORY

The development of a large magnesium industry in North America was delayed until the World War II period. In 1938, the sole producer of magnesium was Dow Chemical. In 1938 the total production of magnesium metal in North America was 2500 short tons. In 1943 the total production of magnesium metal was about 190,000 short tons in the US and Canada. There were 13 primary magnesium production plants built in the US with US government funds by the Defense Plant Corporation. Six were electrolytic and seven were silicothermic. There was one silicothermic plant in Canada. In addition, there was the privately-owned electrolytic production plant of Dow at Freeport, Texas and the privately-owned carbothermic plant of Kaiser at Permanente, California. There was a massive build up in Primary production capacity and also in foundry capacity. The development of any semblance of an organized scrap industry was delayed until after World War II. During the rapid expansion of the magnesium industry, the development of magnesium scrap handling techniques was basically left to the individual companies. Many innovative schemes were developed in some areas and no systems in others.

The heavy pressure to produce castings and parts for the war effort made scrap handling a minor consideration. There was no shortage of magnesium and the foundries in many cases discarded the gates and risers as well as the other run-around scrap. In spite of this, various reports show that there was a substantial interest in magnesium recovery in some areas. Comstock (3) says, "No data is available on recovery of secondary magnesium in the United States until World War II, when requirements for light metals were high. Large quantities of both old and new magnesium scrap were accumulated during World War II."

The rapid expansion of the foundry industry made on-the-job training a necessity. The losses in melting and in scrapped casting were quite large. Much of the scrap recovered at that time probably would not be created at this time.
POST WORLD WAR II ACTIVITIES

After World War II a number of scrap magnesium operations were developed. They could be divided into several basic types. Some were scrap dealers who obtained such things as aircraft engines that contained magnesium and aluminum parts. These engines were dismantled and the aluminum and magnesium parts melted down into secondary ingot. There were melting furnaces erected in the US Southwest right on the site where vast squadrons of obsolete war time bombers and fighters were chopped up and the aluminum and magnesium remelted right on the spot. In many of these latter cases, there was no attempt to maintain any alloy composition, the total material was separated by type and melted and cast into "sweated sows or pigs" as the case may be. This material was then sold to secondary aluminum or magnesium companies to be upgraded into a clean, secondary alloy. Most of these operations died out after the war surplus equipment was gone.

The magnesium industry in the US generally collapsed after the war and primary magnesium production went from low to high to low in an extremely rapid fashion.

Table I – Magnesium Production and Capacity in the United States - 1939 - 1946

<table>
<thead>
<tr>
<th>Year</th>
<th>Primary Production</th>
<th>Production Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1939</td>
<td>3,350</td>
<td>na</td>
</tr>
<tr>
<td>1940</td>
<td>6,251</td>
<td>na</td>
</tr>
<tr>
<td>1941</td>
<td>16,295</td>
<td>na</td>
</tr>
<tr>
<td>1942</td>
<td>48,963</td>
<td>192,000</td>
</tr>
<tr>
<td>1943</td>
<td>183,583</td>
<td>293,000</td>
</tr>
<tr>
<td>1944</td>
<td>157,100</td>
<td>293,000</td>
</tr>
<tr>
<td>1945</td>
<td>32,792</td>
<td>104,000</td>
</tr>
<tr>
<td>1946</td>
<td>5,317</td>
<td>18,000</td>
</tr>
</tbody>
</table>

In many cases, the scrap magnesium operations existed off the stockpiled scrap such as gates and risers. One prominent scrap operation received its start from recycling a dross pile at a shutdown government silicothermic magnesium plant. After the shutdown of production and the government facilities, there were very few surviving scrap operations. Many of the secondary salvage operations were based on aluminum and in many cases did not take a great deal of time in separating the magnesium.

MAGNESIUM TRANSITIONAL STATUS DURING THE 1970s & 1980s

The magnesium scrap industry underwent a transition during the 1970-1980 period. The ready availability of magnesium scrap disappeared. Smelter and brokers had to work long and hard to obtain magnesium scrap. There were many reasons for this. The old source of magnesium scrap from Volkswagens had about disappeared. After the wartime scrap had been depleted, the next big boom for the magnesium scrap industry was the Volkswagen scrap. First, from the US sources and then from European sources. During this period (from 1960-
1980) there was also foundry scrap from a number of foundries, dockboards, litho plate and some extrusion scrap. There was also magnesium released from the government stockpiles that could be purchased by bidding.

At the same time, several things happened that drastically affected the magnesium scrap market in the US. The price of magnesium increased rapidly. The Volkswagen horsepower increased. The government stockpile disappeared.

The increase of the price of magnesium from $0.36 per pound in 1970 to $1.53 in 1985, caused a complete restructuring of the use of magnesium in wrought or fabricated products including castings. Lawnmower decks and similar items were converted to aluminum. Many other items including dockboards were converted to aluminum strictly on a cost basis. This had the effect of lowering the amount of scrap coming into the system.

The Volkswagen Beetle was removed from production in most areas and that caused an eventual great reduction in this source of scrap. While the Beetle is still produced in small quantities, it has been difficult for magnesium from the scrapped cars to be gathered and shipped into the US magnesium scrap industry. As the Volkswagen Beetle became more modern, the horsepower requirements grew. A magnesium alloy had to be developed that resisted the heat. AS41 was developed to replace AZ91. Later the increase in power and design caused the Volkswagen to convert the engine materials to traditional cast iron blocks and heads. This, in turn, reduced the flow of magnesium scrap into the market.

The government stockpile was declared surplus and some 150,000 tons were sold into the market. Much of this material was offered in large lots, but it replaced scrap in many smelters that converted the worst (badly oxidized) metal to clean ingot by re-melting and refining. In some cases, they were able to pickle (acid clean) the ingots in large tanks, rinse them thoroughly, and dry the ingots. The ingots were re-bundled and sold back into the primary market for the same price as new, recently produced ingot.

The Defense Department programs were gradually cut-back with the advent of no cold war. The amount of castings and sheet required for aircraft and missiles was drastically reduced. The longer life of aircraft caused a cautious and careful review of the properties that could cause problems. With aircraft, such as the B-52 lasting over 40 years, Air Force and Navy groups reviewed the corrosion history of magnesium parts. One conclusion was to ban the use of magnesium in Navy planes.

The higher selling prices for primary magnesium boosted the secondary price. However, the higher price also forced the smaller foundries out of business. This decreased the amount of castings going into the scrap cycle and also reduced the amount of scrap available from the foundries. It also reduced the markets for commercially recycled magnesium ingot.

Many of the first secondary smelters were established to produce cathodic protection materials. In particular, pipeline anodes. After the war, there was a boom both in cross country pipelines and in distribution systems as the new homes were built. This market slowed after the boom stopped, but still accounts for 10-20% of the use of smelted scrap magnesium. The original anodes made from recycled magnesium were called "H-1" or "High Current" anodes. They were usually from a modified AZ63 type of alloy. The anodes were placed in bags of "backfill", a mineral chemical (such as sodium sulfate) that helped maintain the anode's constant current output. With this type of packaging and being buried next to a pipeline, the
effects of inclusions or chlorides in the metal were hidden. One original producer of anodes from recycled magnesium said, "We bury our mistakes".

Dow introduced the M-1 or "High Potential" anode. This anode was made from pure metal and only had a small amount of manganese added. It could not be produced from scrap or secondary metal. This affected the secondary producers and they lost market share. Also, the scrutiny on construction and cathodic protection quality picked up as more and better instruments were developed. With many federal programs in housing and later in pipeline review, the small producers of recycled anodes were forced out of the business. Many qualifying tests had to be run to prove the anode's quality and current supplying ability. The small and even some larger foundries got out of the business.

The total effect of tightening environmental controls was to force some of the older operations out of business. It also made it more difficult for new companies to get into the magnesium business because of the stringent permitting required to get construction permission. This affected both the secondary industry and the foundry industry alike.

The higher prices for the materials made many foundries conscious of the value of the scrap that they produced. Some were prompted to set up their own re-melting programs for materials that they had previously sold into the scrap market.

All of these situations combined to increase the demand for the scrap that was available. The price increased. Wakesburg and Garino (4) said in August of 1985, "With VW scrap becoming more and more difficult to acquire in the U.S. and very little (if any) materials coming in from abroad, the few solitary magnesium smelters are facing a challenging time. Analysts in the mid-1980's could see "little optimism for the scrap smelting industry, particularly in view of its inability to secure enough scrap."

METHODS AND TYPES OF MAGNESIUM SCRAP BEING HANDLED

Types of Scrap

Magnesium scrap is available from a number of sources. The classification of magnesium scrap used by the National Association of Recycling Industries (NARI), [now International Society of Recycling Industries (ISRI)] lists six categories of magnesium scrap. These include Clips, Scrap, Engraver Plates, Dockboards, Turnings, Fragmentized scrap.

The ISRI terms are very generic and open to interpretation. The actual operation of the scrap system is still based on many deals between people. Both are expecting to benefit from the transaction and the terms and conditions are usually agreed upon between people. The magnesium scrap classification system developed by Magnesium Elektron (MEL) is shown in Table 11.

Actually, in today's magnesium scrap market, the scrap is divided into Type 1 (Class 1) which consists of clean magnesium scrap such as gates and risers and incomplete castings. Most of this scrap is from die casting operations. The sand foundries that remain in operation are quite small and in most cases re-melt their clean gates and risers and sell the rest to secondary smelters. Descriptions of Class 1 scrap used by Norsk Hydro are shown in Table III.
There are few operations that melt "old" magnesium scrap. With the growth projected in the die casting industry, the Type 1 market is the mainstay of any major recycling operation.

Table II - MEL Scrap Classification

<table>
<thead>
<tr>
<th>Type of Scrap</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>High grade clean scrap eg: Scrap castings, biscuits, etc.</td>
</tr>
<tr>
<td>Type 1B</td>
<td>Clean Scrap with a high surface area eg: Thin wall castings, flashings, etc</td>
</tr>
<tr>
<td>Type 2</td>
<td>Clean Scrap with steel/aluminum inserts. NO COPPER OR BRASS contamination</td>
</tr>
<tr>
<td>Type 3</td>
<td>Scrap castings, painted with/without inserts of Fe/Al. NO COPPER OR BRASS</td>
</tr>
<tr>
<td>Type 4</td>
<td>Unclean metal scrap eg: Oily, wet, contaminated. May contain silicon contamination</td>
</tr>
<tr>
<td>Type 5A</td>
<td>Chips, swarf, machinings. Clean/Dry/uncontaminated</td>
</tr>
<tr>
<td>Type 5B</td>
<td>Chips, swarf, machinings. Oily and/or wet</td>
</tr>
<tr>
<td>Type 6A</td>
<td>FLUX FREE residues, eg: Crucible sludge, dross, etc. Must be dry &amp; silica free</td>
</tr>
<tr>
<td>Type 6B</td>
<td>FLUX CONTAINING residues, eg. Crucible sludges, dross, etc, Should be dry and silica free</td>
</tr>
</tbody>
</table>

Table III – Type 1 Scrap – Norsk Hydro Specifications

Material Description

Class 1 scrap refers to clean process arising from die casting operations, i.e., runners, biscuits, trimmings and rejected cast parts.

REJECT CASTINGS CONTAINING INSERTS, PAINTED PARTS, AND/OR MACHINE TURNINGS ARE EXPRESSLY EXCLUDED FROM CLASS 1 SCRAP.

Chemical Specification

The material should be segregated according to ASTM alloy series, namely: AZ series; AM series; and AS series. Loads should comprise exclusively one alloy series from the above list. Customers casting several Mg. alloy series, or other non ferrous metals, are requested to pay strict attention to avoid the accidental mixing of scrap.
Table III (cont’d.) – Type 1 Scrap – Norsk Hydro Specifications

Physical Properties Specification

1. All material should be free from oil, water, dirt, slag, dross.
2. Customer accepts responsibility to ensure that the material, whether in bulk or containers, is free from extraneous materials and other metal or alloys, including, but without limiting, the generality of the foregoing:
   a) Combustible materials, such as wood, plastic, paper products, oil and grease. (Normal die lubricant traces are acceptable).
   b) Oxidizing materials, such as fertilizers, or other chemicals.
   c) Aerosol containers or any other closed pressurized vessels or containers, including fire extinguishers.
   d) Flammable materials or vessels which may have contained such materials.
   e) Metallic foreign materials: steel, copper, brass, lead, tin, aluminum, stainless steel, or other heat or chemical resistant materials.
   f) Radioactive materials.
3. Dimensional limitations:
   a) Each piece of scrap should be contained within a volume of 1000 mm x 700 mm 400 mm.
   b) No solid cross section of any part should exceed 100 mm x 100 mm.

Lot Definition

A lot should consist of one truckload. Each lot should be identified with: serial number, name of customer, date of shipment, composition of the material (i.e. ASTM Alloy Series), net and gross.

Packaging and Shipping

1. Material needs to be kept dry in process and prior to shipment:
   a) Bulk: material can be shipped in bulk, as far as means are provided for simple and safe discharge of the load, and agreed by N.H.C.I., prior to first shipment
   b) Containers: use of re-useable, stackable containers of approved design is permitted. N.H.C.I. will endeavor to provide these containers.
2. Transportation will be the responsibility of N.H.C.I.

Quality Control

1. Each shipment should be accompanied by the certificate of conformance overleaf, duly signed by an authorized customer representative.
2. Material not meeting this specification would be subject to reclassification or rejection. In the latter case, the customer will assume responsibility for all freight charges.
3. In order to ensure a good mutual understanding and application of this specification, N.H.C.I. personnel are available to assist the customer during qualification and via periodic audits.

The scarcity of good clean scrap has given die casters with large quantities of clean scrap an excellent bargaining position. Some of the smelters can offer the scrap generating
facility a better service. They may also take the dross and skimmings and gates and risers and sawdust from the saws, etc. Some deliver foundry ingot and pick up scrap at the same time.

In the last 10-15 years, there has been another factor in the scrap purchasing market. The Powder Producer. Some of the powder companies can produce powder direct from scrap. They, therefore, only want the best foundry and extrusion scrap, clean with no oil or foreign matter. The Powder Producer will offer a price that is much higher than the usual scrap market to get this material. With the increase in casting price and the fact that the powder producers have learned to directly convert clean scrap to powder has impacted the scrap situation. Whereas the smelters or an export market ultimately had control of magnesium scrap, the powder manufacturer is now in direct competition. In many cases the price has been raised to a point where the foundries can get a better deal by selling the scrap.

Powder producers have also developed mechanical systems, which can take magnesium turnings and borings and chips and convert them to powder through proprietary production methods. Recently, the Chinese magnesium industry has been producing powder and slowly taking up a large portion of that market since they sell at a very low price. It has been reported that in 1998 there were 35 plants producing magnesium granules and powders with a total annual capacity of 45,000 tpy. Magnesium powder is not presently covered by the antidumping duties applied against pure magnesium from China. The powder can be shipped into the US with only payment of normal tariffs.

Magnesium Scrap Processing Methods

In reviewing the various scrap processing methods, we have seen no major new methods. The use of induction furnaces was new, but not too many details were available about the effects of the induction fields having a direct impact on the metal processing or quality.

Most scrap melting is done with externally fired, steel crucibles in a furnace setting. The holding furnaces (where they are used) may be electrically heated. Metal transfer is by mechanical pumps, electromagnetic pumps, siphons, tilting furnaces, and hand ladling in some instances.

The original scrap recyclers had very simple operations. They installed crucible furnaces and bought old scrap and melted it down and cast the magnesium into molds, usually doing all operations by hand. Of course, this limited the size of crucible that could be used, since a man had to stir it and hand ladle the metal out of the crucible and then take the remaining sludge out of the bottom so more metal could be melted.

All of the operations used mixtures of anhydrous chlorides to protect the metal surfaces and to clean tools and the metal was ladled into ingot conveyors or static ingot molds. The magnesium was refined in the pots by use of stirring and flux.

There were two basic fluxes. The melting flux which was fluid and low melting. This flux was used to protect metal during melt down and also protected the surface of the metal in the crucible. Most of the pots during this period were open top with no great ventilation. The refining or Heavy flux contained Calcium Fluoride and at times Barium Chloride. This was the dry flux or inspissating flux. This flux was stirred into the molten magnesium, at first by hand, later by stirrers of many varied designs powered by both electric and/or air motors.
Table IV - Estimated Range of Operating Costs

<table>
<thead>
<tr>
<th>Major Cost Item</th>
<th>Dollar Cost/lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>0.05 to 0.15</td>
</tr>
<tr>
<td>Flux</td>
<td>0.01 to 0.03</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.01 to 0.03</td>
</tr>
<tr>
<td>SF6/CO2</td>
<td>0.02 to 0.07</td>
</tr>
<tr>
<td>Power</td>
<td>0.04 to 0.06</td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.04 to 0.06</td>
</tr>
<tr>
<td>Miscellaneous Costs</td>
<td>0.01 to 0.03</td>
</tr>
<tr>
<td>Replacement Crucibles</td>
<td>0.01 to 0.2</td>
</tr>
<tr>
<td>Replacement Crucibles</td>
<td>0.01 to 0.2</td>
</tr>
</tbody>
</table>

Total for small recycling plant 0.19 to 0.45/lb.

The largest evolving problem is the production of clean, inclusion-free ingots. The method of determining the cleanliness is still under development and there are various arguments for each type that has been developed.

At the present time, there is no all-encompassing purity specification for recycled magnesium to be supplied back to die casters for production of automotive castings. Many methods are being developed, but there seems to be a lack of a fully reliable, cost effective review system.

There are other programs that are being installed to recycle dross and other materials used the magnesium industry (5). The dross is recycled to fertilizer products and metal and then very little is left to landfill.

SIZE OF THE MAGNESIUM RECYCLING INDUSTRY

Introduction

A major magnesium report (6) estimates that the total world secondary magnesium production not including China and CIS was 98,800 metric tons in 1998. This has grown from their estimate of 23,800 tons in 1993. The estimates are said to include die casting scrap which is toll-processed by primary producers.

This particular group uses a series of benchmarks to estimate the amount of secondary or scrap production used in the various key end-users for recent years. They do not add magnesium recovered from recycled aluminum beverage cans.

They say that "the use of secondary material has grown in recent years, as rising volumes of die-cast shipments have brought rising scrap returns from the die casters. In addition, earlier in the 1990's, a greater proportion of die cast material was recycled by die casters themselves, in house. Market growth has brought with it more consumers prepared to send material to dedicated recycling units, whether they are associated with the primary producers or independents."
In the study and development of the background of this report, the total recycling numbers appear low.

**Die Casting Scrap**

The yield of the die casting process has been estimated at 50% by several authors. (7) This number is said to vary by company and by part and by die casting process, i.e. Hot chamber having less loss in runners and biscuits than cold chamber.

Further discussions with some industry experts say that a conservative number is that one out of every three pounds, shipped to a die caster is scrap that can be tolled. This would mean only saying that the scrap from pouring and the scrap from casting was to be re-melted.

The International Magnesium Association report for 1999 said that shipments to die casters reached 133,500 tons (8). That would mean there would be 66,750 metric tons of scrap or loss. Of the total loss, 41% would be Type 1 scrap for recycling, 5% would be dross, 5% returns and 36% gates, runners and trim scrap. That would give about 54,735 tons for Type 1 recycling.

The Bureau of Mines numbers in their annual magnesium report for 1999 (9) for new scrap and old scrap look to be very small. However, if we use the ratio of new scrap and old scrap in the report as being 0.56, then if 54,735 tons is new, 30,651 tons would be old. This would give a North American total for 1999 of 85,386 tons for recycling.

Based on the capacity calculations and some guesses, recycling demand will increase. It has been reported by Financial Times (10) that by the year 2003, 194,000 tpy of magnesium will be shipped to die casters. Following the former report and premises, that will mean there will be 79,540 tons of new Type 1 magnesium scrap to be recycled in North America. This may require new recycling facilities, either Brownfield expansions or new Greenfield projects. This whole picture could also change if new and improved die casting processes improve the yield of castings compared to metal melted. The picture could also change if more die casters recycle their own magnesium scrap in house.

**REFERENCES**


